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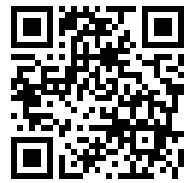

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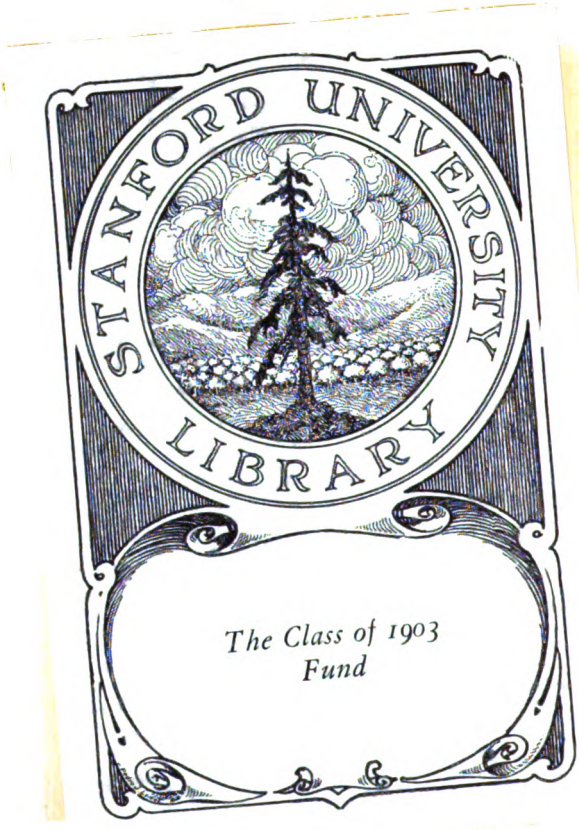

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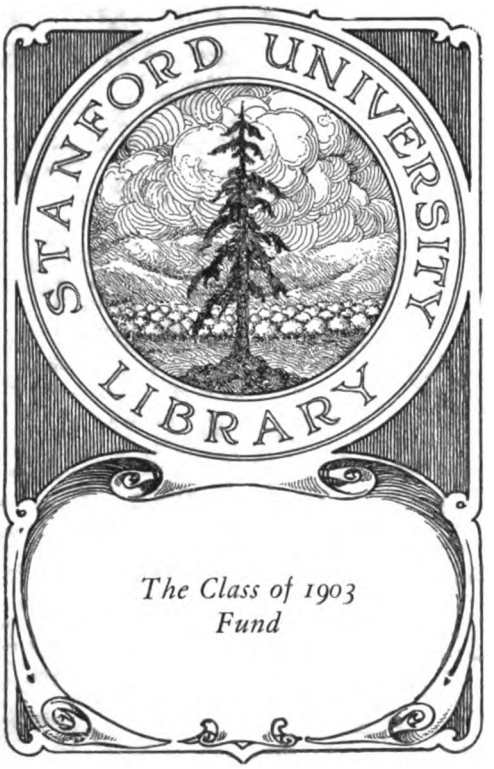

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QUARTERLY JOURNAL

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MEASURING SUN RAYS.

By Prof. C. G. ABBOT, Hon. Member.

Director, Astrophysical Observatory, Washington, U.S.A.

[A Lecture delivered before the Royal Meteorological Society on November 11, 1925.]

MR. PRESIDENT, LADIES AND GENTLEMEN,

I thank you for this opportunity to address the Royal Meteorological Society. It is one which I appreciate as a great honour, and at the same time as affording me an occasion to present to the most discriminating of audiences a heresy which I hope may soon become an article of faith. My proposition is this: The sun's output of radiation, when most accurately measured, still exhibits fluctuations, small and irregular in range and duration. These apparent solar variations seem to be correlated in a complex but important way with following changes of weather.

I am quite justified in calling this a heresy. Professor Marvin, the Chief of the United States Weather Bureau, than whom nobody could be more orthodox, states in the July issue of the *Monthly Weather Review*: "It is futile to hope to establish any scientific basis for weather forecasting on supposed changes of solar constant before we know that the constant does change from day to day, and if it does, how much." To this I make reply: "The adoption of solar variability as a working hypothesis has already yielded, in the hands of Clayton, Arctowski, Nansen, Walker and others, meteorological correlations which are now actually being used with a moderate measure of success in the official long-range forecasting of Argentina and in the private long-range forecasting of Clayton." And now, having joined battle with my adversary, it is time to give the evidences on which I rely for victory.

The apparent variation of the sun is disclosed by daily measurements made by the Smithsonian Institution on two desert mountains. One station is in the nitrate desert of Chile, and the other in the desert region of south-western United States. These two stations measure independently the intensity of heat derived from the sun's rays. There lies above each station an ocean of atmosphere, in which molecules, dust particles and humidity all play large and various parts to reduce the intensity of the direct solar beam. Our measurements enable us to estimate these losses so that we can compute the heat which would be obtained from the solar ray if the observer could go entirely outside the atmosphere, for instance, to the moon.

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Allowing, also, for variations of the sun's distance, we thus come to determine five times, on nearly every day, from each of two desert mountain stations the intensity of the solar beam in free space at the earth's mean solar distance. This quantity is usually called the solar constant of radiation.

Before considering the variability of the "solar constant," I may remark that neither the ancient kings of Egypt and the East, nor our modern philosophers and observers prior to 1900 have left any records fixing the mean value of the solar constant within wide limits. In the great meteorological text-book of the late Dr. Hann, of Vienna, published in 1901, he states values of it ranging from 1.76 calories to 4.0 calories, and expresses no preference between them.

During the past twenty years, the Smithsonian Institution has made several thousand measurements of the solar constant in every season of the year, from nearly a dozen stations, ranging in altitude from sea-level to 15 miles above sea-level, and under atmospheric conditions ranging from the hazy humidity of summer at sea-level to the extreme purity of the air above a balloon at 15 miles elevation. All of these values are in close accord. They enable us to record for posterity the average intensity of the sun's emission during our generation so accurately that no permanent change exceeding 1 per cent. in its average output need escape the meteorologists of the future.

Although these numerous determinations fall within a narrow range, they yet show what seems to be two distinct sorts of variation. The first is associated with the march of sun-spots. Apparently the sun's emission of radiation is about 2 per cent. greater at sun-spot maximum than at sun-spot minimum. This might well be expected. When we stir an open fire, and bring hotter coals to the surface, it throws out more heat. So the sun, being highly agitated from within by the activities of various kinds accompanying sun-spot maximum, should then present hotter gases near the surface, and thus should radiate more strongly.

In the second place, we find, superposed on the long period fluctuation, solar variations of briefer, irregular interval, ranging up to an extreme magnitude of at least 5 per cent. Seeking for their cause, we discover that they are also associated with visible solar phenomena. It appears, in short, that almost whenever a sun-spot group, in its march across the solar disk, reaches the central position, there occurs a depression of solar constant values. Correspondingly, your eminent magnetician, Dr. Chree, has lately disclosed that days of greater disturbance of terrestrial magnetism attend lower solar radiation.

On the other hand, when lively outbreaks of the bright solar faculæ are seen at four or five days' march from the centre of the sun's disk, higher solar constant values are apt to occur. During a long period of quiescence the solar radiation seems to be apt to decline. The appearance or rapid growth of a sun-spot group at such a time is attended by higher values.

We see in all this a hint that the solar surface is of unequal transparency and unequal temperature. The sun-spot regions would seem to be surmounted by soaring gaseous columns adapted to

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restrain the rays. Possibly these may be associated with the solar corona. As the sun revolves, new radiating surfaces of greater or less brilliance appear, and as the rays of lower transparency which surmount sun-spots interpose centrally, the earth receives less radiation. In this way rapid solar changes are possible, for the sun rotates more than 13° each day.

A conspicuous example of such a change of radiation accompanying the passage of a great sun-spot group over the centre of the solar disk occurred about March 20, 1920, when conspicuous Northern Lights and magnetic storms also occurred. But such phenomena are very generally observed. Mr. Clayton, indeed, has computed from our data of several years the average curve of solar radiation changes accompanying the whole march of sun-spot groups for the complete period of solar rotation. His curve gives the mean result for a very large number of spots, and shows not only the depression when spots point centrally towards the earth, but a hot and cold side of the sun and subordinate features.

I think you will see from these illustrations that a comparison of our solar radiation work with visible solar phenomena gives a number of evidences of the reality of substantial solar constant changes. The confirmations of the reality of solar variation are completely ignored in the deprecatory statistical conclusions of our friend Professor Marvin, the Chief of the United States Weather Bureau. I hope that some of you will read my answer to him in our American popular journal *Science*.

About ten years ago, Mr. H. H. Clayton, then official forecaster of Argentina, desiring to find means to extend his forecasts, adopted the idea that our results actually reveal solar variation as his working hypothesis. He sought to find what weather changes, if any, are associated with these apparent solar changes. He soon obtained such obvious correlations with weather phenomena as induced us, in 1918, to instal a new observatory in Chile, in order to observe all the year round, instead of during summers only, as before at Mount Wilson.

By that time Mr. Clayton had reduced his results to a system of long-range weather forecasting for Buenos Aires. From December, 1918, until now, we have regularly furnished the Argentine weather service with daily telegrams from our Chile station, giving observed solar constant values. Official weekly forecasts of the temperature and rainfall for Buenos Aires are based thereon and sold by the Argentine Government to clients.

In a recent paper,[1] Mr. Hoxmark, successor to Mr. Clayton as official forecaster of Argentina, has given an illustration showing the forecasted and observed temperatures and rainfall at Buenos Aires during 12 consecutive weeks in the year 1924. In general, the agreement is rather satisfactory. Occasionally, however, the forecast is opposite to the event in all its details for several days.

Mr. Hoxmark also gives correlation coefficients between forecast and event for 131 consecutive weeks. Their average value is but +16 per cent. When the three months of poorest weather for solar observations, December, January and February, and the two

[1] *Smithsonian Miscellaneous Collections*, Vol. 77, No. 7.

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months when it is most difficult to foresee whether solar effects will be positive or negative at Buenos Aires, namely, May and October, are removed, the remaining seven best months of the year give a higher average correlation coefficient of +21 per cent.

Curiously, however, even among the 80 weeks occurring in the seven best months, eight weeks show negative correlations between 30 and 60 per cent., and no less than six weeks show negative correlations exceeding 60 per cent. Had the forecaster been wise enough to reverse all these high negative predictions he would have attained a general average correlation coefficient of +37 per cent.

It is not beyond hope that such wisdom may soon be gained. Neither is it doubtful that the solar radiation observations, on which the whole fabric of this long-range forecasting depends, are capable of greater accuracy. Thus, a decided advance in the character of the long-range forecasts is to be expected before long.

Yet even in their present state Argentine clients are quite willing to pay for these weekly forecasts as real aids to business. The Argentine Government, in fact, has recently equipped an observatory at La Quiaca, Argentina, to measure for itself the solar variation, and purposes to continue the solar forecasts indefinitely.

During the past two years Mr. Clayton, having retired from his connection with Argentina, has been studying these solar relations with the weather of North America. He found similar, though possibly more complicated, effects of solar variation on both temperature and atmospheric pressure. There appears to be a great centre of action in Western Canada which responds within a few hours to changes in solar radiation. Three or four days are required to bring these effects to the sea-coast cities of Boston and New York. In general, increased solar radiation portends lower temperatures of our eastern cities.

This may seem a paradox, but one should recollect that the direction of the wind plays a great part in temperature conditions. The winds blow in their great circulatory movements around the regions of maximum and minimum pressures. If, now, these regions of high and low barometer drift about, the temperatures of all stations in their vicinities are subject to change. Clayton's studies show that tremendous displacements of the atmospheric highs and lows attend changes of only 1 or 2 per cent. in solar radiation. These are doubtless the agents of the temperature changes observed.

Nevertheless, the barometer cannot be affected directly by changes of solar radiation. Yet one may see that it can be affected very quickly. For the atmosphere has a large absorption of solar radiation and a small capacity for heat. Consider two adjacent regions of great atmospheric absorption and great atmospheric transparency respectively. If solar radiation increases, the former part of the atmosphere will at once be more heated than the latter, and the expanding air will flow over on to the region of great transparency, increasing the barometric pressure there. It probably is not even necessary for the air to go over bodily through any long distance. The lateral pressure wave, proceeding with the velocity

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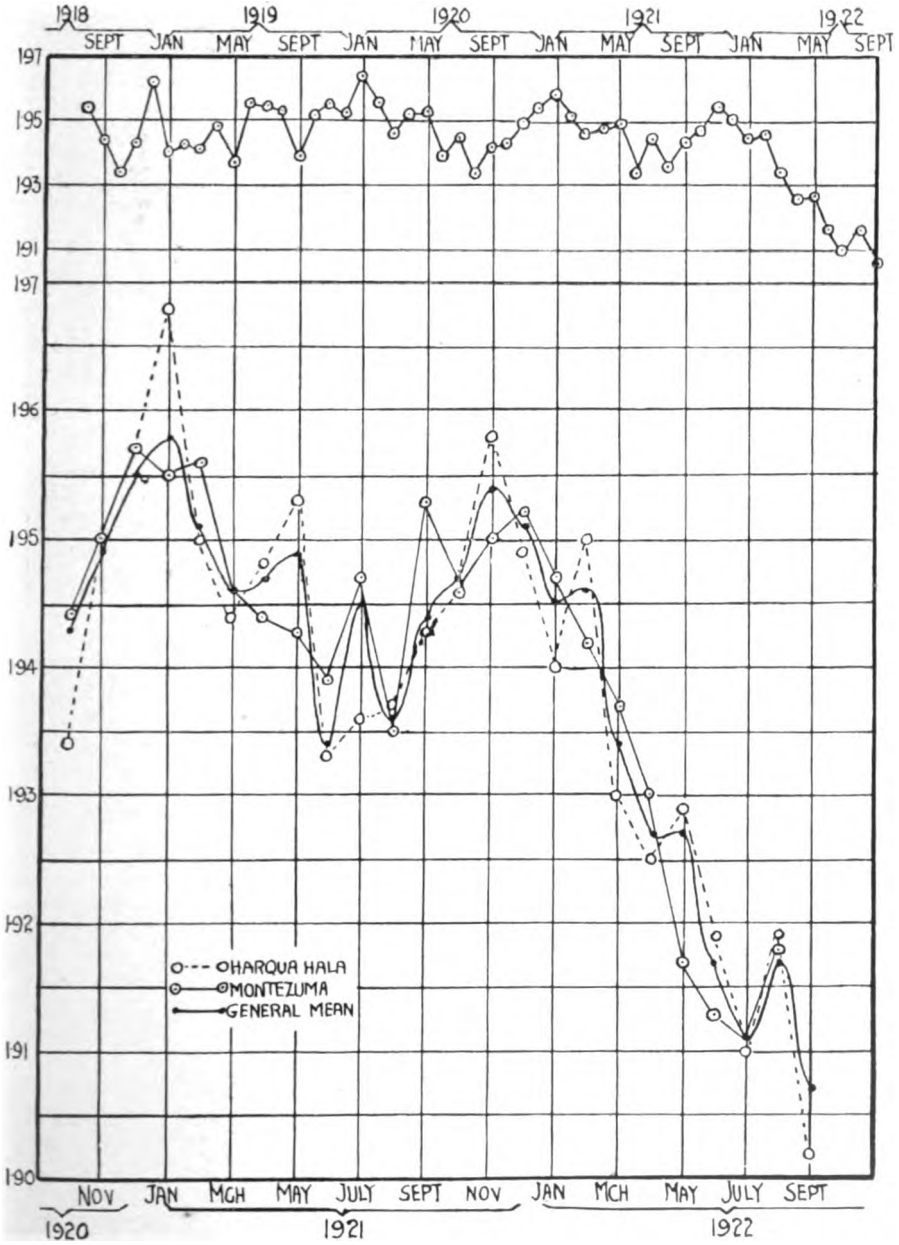

Fig. 1.—Monthly mean solar-constant values and individual results of 1920-1922 at Harqua Hala and Montezuma.

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FIG. 2.—Observing solar radiation at Harqua Hala.

FIG. 3.—Solar radiation apparatus on Mount Whitney (altitude 14,500 feet).

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of sound, would seem to be capable of producing the barometric change in question.

Thus, weather changes may be brought about in certain localities very quickly, corresponding to changes of solar radiation. These primary actions, however, may go on to produce secondary weather changes at great distances after suitable delay. Hence, the solar effects produced on the weather of any particular station are extremely complicated. An enormous amount of statistical work must be done before these effects can be forecasted.

In order to make a practical test of his work, Mr. Clayton has reduced it to a system of forecasting for the great city of New York. For over two years he has forwarded daily to the Smithsonian Institution, several days before the event, definite forecasts of the temperature to be expected three, four and five days after the solar observations on which his forecasts depend. He has also forecasted the expected temperature departures for each week and each month, sending his information three days before the week or month began.

We find that in all of this he shows real prevision. Thus, if we collect all the days which Clayton predicted 4°F., or more, above normal, and compare with all those predicted 4°F., or more, below normal, we find that there was an actual difference in Clayton's favour of over 2°F. Similarly, the weeks and the months predicted above normal averaged for the year several degrees above those predicted below normal.

As yet the degree of correctness is not very high, but it is certainly high enough to make Clayton's solar estimate better than the business man's guess. Moreover, Clayton's forecasts are steadily getting better, though his progress is still held back by the inaccuracy of our radiation data.

This brings me to the reason why I am in England to-night. Clayton's work shows that so little as 0.5 per cent. change in solar radiation is adequate to be associated with a material change in the factors which govern weather. Whether this represents a direct influence of solar heating upon the atmosphere, or an indirect influence, due to much greater percentage variations in the ultra-violet spectrum, and the atmospheric ozone dependent thereon, I cannot say. Perhaps we may find later on that observations with ultra-violet rays will prove a highly useful factor in this research.

For the present, however, we are trying to improve our solar radiation values. The average daily difference between our Arizona and Chile stations is about 0.5 per cent. This means that on many days our estimate of the conditions of solar radiation may be as much as 1 per cent. wrong. Furthermore, although we occupy two desert stations, there are a large number of days in the year not observed at all.

In these circumstances the National Geographic Society of the United States has made me a grant of money to establish a third solar radiation station in the best possible site to be found in the Eastern Hemisphere. There are four principal requirements to be filled. First, a stable government, so that the observers and their outfit will be safe from violence. Second, ready means of communication, preferably by rail. Third, desert conditions of the

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greatest cloudlessness. Fourth, a high altitude, so as to avoid the influence of variable surface dust and humidity.

Apparently there remain but three regions of the globe, remote from each other and from our present stations, suiting these requirements. They are South-west Algeria, North-east Baluchistan and South-west Africa. I am on my way, ladies and gentlemen, to examine these three localities. I hope to arrange at one of them for the cave for instruments and the quarters for observers. Next summer a solar radiation outfit under a competent field director and trained assistant will go forward to occupy the chosen site.

Snow on the Riviera.

Unusually severe weather was experienced in the Riviera during the last days of November. Snow, which had not been seen on the *Côte d'Azur* for fifteen years, except in the mountains which shelter the Riviera from the north, fell on November 29 at Nice, St. Raphael and other resorts. The temperature fell nearly six degrees below freezing point and serious damage to flowers, fruit and the tropical vegetation of the coastal areas was caused.

The Return of the "Maud."

The *Morning Post* of January 2, 1926, publishes an extremely interesting account of the experiences of the "Maud" in her attempt to drift with the ice fields across the Polar Sea. The story is told by the captain of the ship, Captain Oscar Wisting. The company—eight all told—included Dr. H. U. Sverdrup, who was in charge of the scientific side of the expedition, the primary object of which was to collect meteorological, oceanographic, and magnetic data.

Leaving Hope Point on July 29, 1922, the ship on reaching Herald Island became fast in the ice and then commenced her long drift which lasted for just two years. Progress for two months was favourable, the drift carrying them to the north-east, but a continuous spell of easterly winds then bore them hundreds of miles westwards. This was followed by a slow and irregular motion to WNW which brought them, by the beginning of September, 1923, to a position east of De Long's Island (76° 16′NW 163°E).

A spell of northerly winds then prevented them from making any headway across the Polar Sea, and the winter of 1923-4 saw them drifting backwards and forwards practically in latitude 75°N, longitude 155°E. During this period many observations were received at the Meteorological Office and duly plotted in the working charts.

In the spring of 1924, the WNW drift was resumed and on August 9, 1924, they succeeded in getting out of the ice in latitude 75° 25′N, longitude 143°E.

Although unsuccessful in their efforts to cross the Polar Sea, valuable information of a scientific nature has been brought back which will be discussed later by Dr. Sverdrup.

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NOTE ON VARIATIONS IN TRANSPARENCY OF THE ATMOSPHERE BY MEANS OF A PROJECTED IMAGE OF THE SUN.

By CATHARINE O. STEVENS.

[Received May 27.—Read November 18, 1925.]

It is, of course, a well-known fact that if a non-achromatic telescope is employed to give a projected image of the sun, in a darkened room, prismatic colours are to be seen fringing the limbs of the sun's projected image. It seems, however, not to be so well known that these colours vary considerably, and that such variations show a genuine correlation with changing weather conditions.

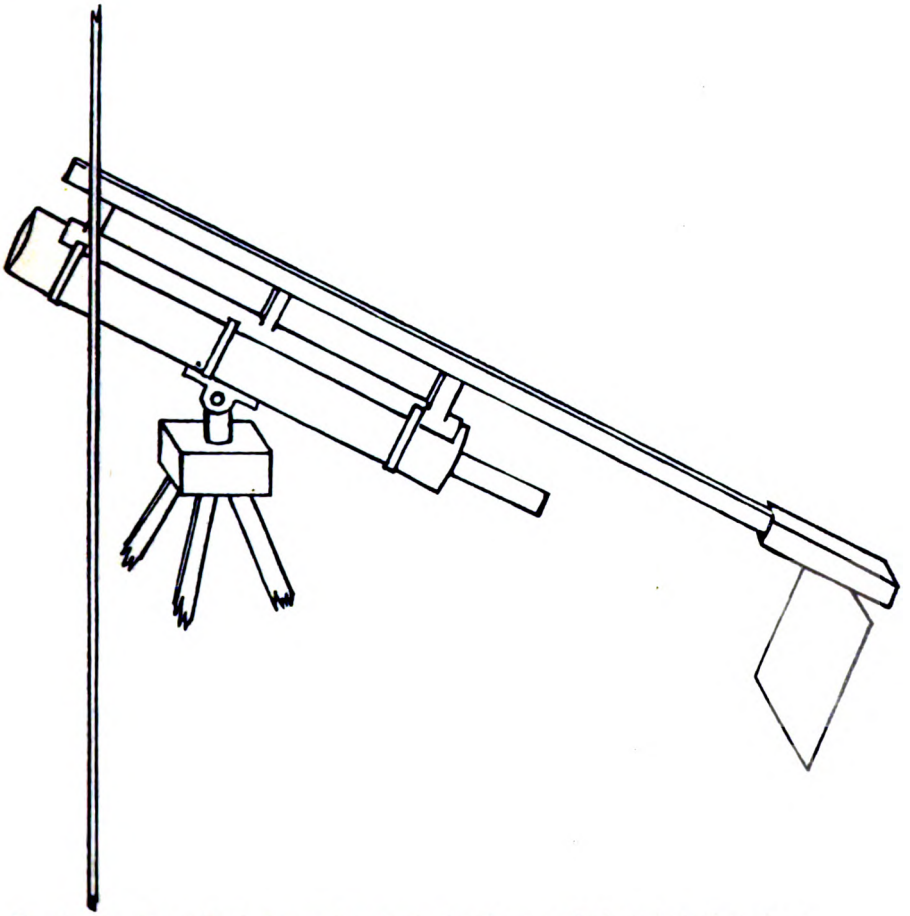

FIG. 1.—Showing method of mounting screen on telescope which projects through an opening on the left of the picture.

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Sir Robert Ball says in his *Story of the Heavens* (p. 450): "A prism is not only full of information in regard to the sun, but also by means of the sun we learn the physical properties of the material composing the prism," and he continues: "The colour of clouds is thus at once an index of the constitution of the source of light and of the constitution of the atmosphere also."

The method employed in obtaining a projected image of the sun is shown in Fig. 1. The telescope is mounted on a tripod stand in a darkened room, the framework holding the screen being attached to the telescope by means of a saddle-back carrier. The distance of the screen from the telescope is adjustable for focussing. This distance was, however, kept constant throughout the experiments, thus ensuring that the changes in the colour fringe scheme are referable only to variations in the transparency of the free atmosphere between the sun and the place of observation. By this method one may watch the effects of those processes, perpetually in operation in the clear air, that not only affect the quality of the sunlight received at the ground level, but that in the schemes of colours variously associated with the sun's projected image, are found also to give premonitory signs of such weather as is in process of development—signs that are not perhaps so readily to be recognised by any other means of observations.

In normal conditions of fine weather—anticyclone and rising barometer—the prevailing tones of colours given by the telescopic image are: Red-orange and bright blue. Any pronounced variation from this is informative:—

1. Green conspicuous.	Rain to be expected.
2. Purple or violet conspicuous.	Electric conditions associated either with snow or thunderstorms.
3. Colours whitened or nil.	Unsettled weather with quick changes of cloud formation, from cirrus to cloud of monster type, with or without precipitation at ground level. Halo-formations or iridescent colours are to be looked for, and fall of the barometer.

The variations are often curiously transitory, frequently associated with the passage of translucent cloud films or with the margins of more substantial clouds.

DISCUSSION.

Sir GILBERT WALKER said he was interested in the paper, because in India they had used that method for recognising the amount of convection in the atmosphere by taking a telescope which was achromatic, projecting an image of the sun and watching the amount of boiling thus shown on the margin. It was interesting to see how that does depend on climatic conditions. For example, in a hill station when the slopes are exposed to the sun, the image of the projected sun would be boiling all round, while, at places in the plains, where you would expect convection to be present, you do not get it on a big scale because the conditions were fairly uniform everywhere and such vigorous up-currents did not develop.

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TABLE I. Observations.

Date.	Time.	Definition.	Wind and Cloud Conditions.	Colour Scheme.	Development.
1903. Sept. 28	11.45 to 12.30	Fair, but varying.	Cloudless.	Considerable variations, finally pronounced modifications in favour of violet with occasional lapses of green.	Brilliant day, finally completely overcast by 6 p.m., later a steady downpour of rain initiated a wet night.
Sept. 29	15.00	——	——	——	Rain has fallen almost without intermission for 18 hours.
	22.30	——	Colourless lunar rainbow.	——	——
Sept. 30.	10.00	Fair, disturbed by wind wave movements erratic in amplitude and confused in direction—convection sometimes excessive.	Two strata of cloud from between south and south-west, a third and more elevated wind wave movement speaking a west wind.	Pale orange and watery blue predominate.	Unsettled weather continued. Later, slowly drifting cloud-veil from west, that effaced all colour.
Oct. 12	10.30	——	——	Strongly pink and green and aquamarine.	This morning and greater part of yesterday, tremendous rain.
Oct. 16	09.30	——	Perfectly clear sky.	Colourless: arrival of clouds of more than one layer is certain. Colour sometimes conspicuous, but then it savours of green types of both yellow and blue.	——
	10.00	——	——	——	Clouds in two layers arrived from west.
Oct. 17	14.00	——	——	Colouring greener than justifies a favourable prediction of weather.	There has been a lot of rain in the past 24 hours; it has not long since cleared.

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TABLE I.—OBSERVATIONS (*Continued*).

Date.	Time.	Definition.	Wind and Cloud Conditions.	Colour Scheme.	Development.
Oct. 18	09.20 to 09.45	Good, in spite of intermittent cloud.	———	Colours generally good, but sometimes a strong invasion of green and a less well-marked, incursion of purple.	———
Oct. 25	11.30	Very hasty view between clouds.	More than one layer of clouds having general direction from between south and south-west.	Remarkably violet.	A day of heavy rainstorms, culminating in tremendous thunderstorm, crisis reached 19.45 to 20.30, with wind and rain of exceptional violence.
Oct. 26	09.15	Image tremendously confused.	Masses of heavy cloud travelling at medium pace above a lower stratum of thin cloud (having rather crisp margins) racing below. Both layers of nearly same direction, *i.e.*, west.	Colourless.	No record.
Dec. 2	?	Observation of moon.	North-east wind for last two days, very hard frosts.	Green tone very pronounced.	———
Dec. 3	03.00	———	Thick fog, wind gone round to south-west.	———	Barometer fallen considerably, all frost entirely gone.
	20.00	———	———	———	After nightfall violent gale with heavy squalls of rain at intervals. Days of unsettled weather followed.
1904. April 4	09.30	Poor.	At least two strata of thin translucent cloud, having nearly the same direction of drift, and that give total obscuration when in transit together.	Mostly yellow.	Fine mostly. Eventually entirely overcast. Some rain fell at 17.00. Heavy rainstorm 18.50 to 19.00. Heavy rain in the night.

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April 6	10.00	Good, but not excellent owing to wind wave movements being quite wild in irregularity of amplitude, although exceptionally unanimous in direction.	The several stratifications of wind quite clearly distinguishable, although having exceptionally unanimous direction.	Colours for fair weather: No green, often traces of purple.	Fine throughout the day. Roads that were very wet in the morning, dry and dusty even before night.
April 7	10.00	———	Frequent obscuration and almost perpetual interruption of observation by transit of semi-transparent vapours racing over the disc from between west and west-north-west.	Very varying, with passage of cloud all rendered very colourless. At other times good blue and good red orange, but with green and purple also.	During the night following a lot of rain fell.
April 8	13.45 to 14.00	Very good.	———	Varied during observation. Mostly good blue and good orange, but never red enough for "settled fine" weather.	Cloudy morning after wet night. Fine afternoon. Overcast evening, with some showers. Starlight night.
April 9	14.40 to 15.00	Very good.	Observation interrupted by transit of soft, dense cloud masses.	Blue, clear and true, good red orange, but more green and purple than guarantees settled weather.	Brilliant all day from 11.00 onwards.
April 10	—	Very good, but sun's limb very much torn by wind wave motions.	Cross currents of wind in three clearly marked layers. Observation interrupted by passage of clouds more soft and more moist looking than yesterday.	Green conspicuous, in fact green and yellow out-do the red-orange tone altogether. Blue satisfactory.	———
April 11	10.30	Good.	Thin vapours often transit, that are only just visible in the telescopic field outside the image of the sun. They pass without visibly affecting the definition of the sunspots.	Remarkably purple during transit of thin vapours. No green at any time. Blue and orange well in evidence.	———

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TABLE I.—OBSERVATIONS (*Continued*).

Date.	Time.	Definition.	Wind and Cloud Conditions.	Colour Scheme.	Development.
April 14	10.40 to 11.30	Far from sharp.	Two layers of filmy translucent cloud perpetually in transit, the higher formation the more persistent and also by far the more dense and moist looking — frequently obscuring the sun.	Nondescript to begin with, but varied extraordinarily. Green at times predominated, at other times purple—intervals of normal "fine weather" colouring alternated with nondescript colouring.	April 15. Hours of heavy rain. Brilliant evening. Starlight night. Conspicuous display Zodiacal light.
April 16	14.10	Very clear.	Cumulus clouds in lovely masses.	No green, occasionally strong purple and good blue.	——
April 17	09.45 to 10.15	Rather unsteady, generally very good.	——	Green faintly in evidence. Blue good. Red and yellow not good.	Barometer rising.
April 18	09.15 to 10.00	Very good.	——	Green rarely in evidence. Blue paler than for "settled fine." Red-orange generally excellent. Purple a good deal in evidence.	Barometer still rising till past 13.00, by 15.00 visibly falling.
April 19	10.30 to 11.15	Good, but at times a little fogged.	——	Red-orange strong. Blue good, often over-run with purple. Green in a minority altogether.	Heavy rainstorm 17.00. Starlight night. Fine display Zodiacal light. Barometer rising.
1919. Sept. 21	09.20	Poor.	Cloudless, highly elaborate stratification of wind movements.	Palest blue and green. Green might be styled "yellow green" but not "green yellow."	——
	10.20 to 11.06		First transit of visible cloud, very thin fleece, semi-transparent even at its densest. Cumulus also in evidence.	Blue still poor, but now a tone of good yellow-orange.	——

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	11.40	——	——	Iridescence (pink and green, mostly pink) on a single cloud-fleece of highest cloud elevation.	——
	12.11	——	Great increase in cloud.	——	——
	14.50	Fair, but varying.	Sky cleared wonderfully.	Blue good, orange now prevails over yellow.	Air now much warmer, sky clearer than at any time since 11.30.
	17.20	——	General lie of highest cloud formation has changed direction from east-west to north-south.	Translucent cloud effected obliteration of colour to a marked degree. Incomplete obliteration occasion for predominance of green over yellow, which latter returned with sun's re-emergence.	Day turned out better than expected, but all signs give warning of further trouble within 24 hours.
Sept. 22	18.05	——	——	——	Brief precipitation of rain.
	09.50	——	Sky entirely overcast, rain falling.	——	Incessant drizzle on south-south-west wind till mid-day, then an interval of lifting with shift of ground wind to further westwards.
	13.05	——	Entirely overcast, heavy rain falling.	——	——
	14.15	——	Sunshine. Naked eye observations show cirrus of all types converting rapidly into ci.-st., and short-lived ripple clouds of various directions of lie. Some cumulus also.	Blue not so good of its kind as orange, but all colours better than expected.	——
	16.00	——	——	——	Brief precipitation of rain.
	18.00	——	Sky cleared considerably.	——	——
	22.40	——	——	——	Since 19.00 much rain on south-south-east wind, wind rising.

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Mr. BONACINA asked to be informed of the percentage of cases in which the indications of good or bad weather failed, because he did not think that point was brought out in the paper. The principle seemed to him to be very interesting because you were integrating the whole thickness of the atmosphere, not merely taking a single layer as an indication of coming events. The principle was worthy of development for that reason.

The PRESIDENT observed, in reference to a suggestion which had been made in the discussion that Miss Stevens was using the telescope like a rain band spectroscope, that it was not in the green that the rain band occurred, but between the red and the yellow. He was old enough to remember when the rain band spectroscope was almost a novelty. Near sunset, when the rain band was very pronounced, there was practically nothing left in the spectrum but the green, and he imagined that on certain occasions in stormy weather when the sky was green, this meant that the rain band was very pronounced. Whether it was a fact that if the rain band were present, then rain was coming, was, he thought, a question which had never really been decided.

Mr. J. E. CLARK said he had made records of the rain band in the spectroscope for some years during the eighties, and when it was exceedingly pronounced it was helpful in getting a local forecast. That was at a time when the London forecast arrived in Yorkshire the next day, and he was asked from what he saw through the rain band to make what forecast he could and generally he was able to give a little help, although it was very precarious. In reply to a question as to how the observations were taken, he explained that they were taken across the sky and facing up into the wind and always at the same angle, which was, he thought, at 30° with the horizon so as to get a similar thickness of the atmosphere in the observations.

Miss C. O. STEVENS, in reply, wished to add that what called her attention to the idea that her news might be of any value, was a paper which she had seen which dealt with the subject from the medical point of view. She felt that although she was such a complete amateur and simply an observer using her telescope, she really did get the knowledge that there were absorptions of this or that particular sort from day to day, and therefore if it should be of any particular benefit in open-air treatment cases to know what sort of quality of sunlight was being dealt with on any particular day, the officials at the open-air treatment places might do as well as she did in ascertaining whether the sunlight was good blue or good red-orange, and know the qualities of the atmosphere from day to day and benefit the patients thereby. It was a form of simple and reliable observation that could be made by a quite untrained person.

Snow Reports.

With a view to correcting the optimistic note which characterizes many of the snow reports from Switzerland and other places, the *Morning Post* now publishes details received by telegram from members of the Ski Club of Great Britain on the spot. These reports are published with the authority of S.C.G.B. and may be regarded as absolutely impartial and accurate. At present some thirteen centres in Switzerland and the Tyrol are covered and steps are being taken with a view to increasing the number.

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NOTES ON THE BEHAVIOUR OF CERTAIN PLANTS IN RELATION TO THE WEATHER.

By NORMAN L. SILVESTER, M.Sc., F.R.Met.Soc.

[Received February 19—Read November 18, 1925.]

For centuries a number of our common weeds have been credited with the ability to forecast the weather by changes in either stems, leaves or floral envelope.

Linnæus observed this sensitiveness and utilized this property in his classification. He described such plants as "meteoric."

Kerner von Marilaun (7) records that "in cloudy, misty and rainy weather" such flowers "remain closed or only partly open, or, when these conditions are but temporary, a conspicuous retardation of opening and closing takes place, which cannot, however, be indicated numerically." He defines the regular diurnal movements as "autonomous" and refers to control experiments made on *Gentiana Rhætica* in which (*a*) plants maintained at a constant temperature of 7° C. opened their flowers in the usual manner after sunrise under the influence of the sun's rays, and (*b*) plants were subjected to a temperature of 42° C. over a hot stove in the dark and yet the flowers opened despite the absence of light. He attempts to correlate the results of these two experiments by attributing to the pigment *anthocyanin* the property of converting light into heat—the inference being that heat is the first cause of the movement. He adds, however, that "these observations offer no complete or satisfactory explanation."

Taylor (2) suggests that it is the atmospheric moisture that is the controlling factor, but he limits the time of the individual flower's usefulness to the period preceding its fecundation. He supposes that the closing of the flower is a precaution against moisture coagulating the dust of the anthers, thus preventing it being blown on to the stigmata. He states that "a very remarkable circumstance attending plants of this class is that when the fecundation is completed, the flowers do not contract either in the day or in the evening, nor at the approach of rain."

Inwards (8) records a number of sayings relating to several of this class of plants. The pimpernel seems to enjoy the best reputation according to him. It has been nicknamed the poor man's and the ploughman's weather-glass; nor has it been misnamed, as it proves to be as unreliable as the solitary barometer in predicting the weather. He records that when the flower of this plant closes in the daytime, it is a sign of rain.

Under the head of "*Plantes Barometriques*," Moreau (9) gives a table of sixteen plants whose behaviour is reputed to be influenced by weather changes. Though he briefly states which element each is supposed to forecast, he wisely refrains from giving his opinion on their value, but suggests that his readers should make their own observations to sift out false from true. In another article (10) he suggests that since, on the approach of rain, stalks of leguminosæ stiffen whilst the flowers of the lesser bindweed, con-

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volvulus and sorrel droop and close, and those of the lettuce and pimpernel expand, the effect of this weather change on the "nervous system" of the plants cannot be uniform.

Humphreys (11) allocates a brief half-page to his criticism of the forecast value of plants. He states "that the changes on which weather predictions can rationally be based are owing to variations in humidity, temperature and sunshine; and that plant signs generally are but poor guides to a knowledge of the coming weather."

Prompted by a desire to utilize all available information for the purpose of local forecasting at a time when the exigencies of the service prevented the prompt transmission of telegraphic forecasts from London, observations were started at Howden in Yorkshire in the autumn of 1917. The state of the flowers of the pimpernel, daisy, dandelion, and sowthistle found growing wild within about 200 yards of the Stevenson screen was recorded several times per diem at irregular hours during the daylight. Notes on the present and subsequent weather were included. The leaves of the clover (*Trifolium repens*) were also watched. A large number of each flower was kept under observation to eliminate possible individual idiosyncrasy, the state of the majority being recorded where differences were noticed.

Similar observations were continued during the late summer and autumn of 1921 in a sheltered garden at Stamford Hill, in a bed as near as possible to the screen which was placed according to official routine at the usual height above a lawn. The latter kindly provided the clover for observation. The drought in the spring of this year effectually prevented the germination of many of the common weeds and no seeds could be obtained. Observations during this season were therefore confined to clover, dandelion and chickweed.

In a garden at Finchley, less sheltered than the former, a more intensive study was resumed during the season of 1923. Here the screen was erected in the centre of a bed with a southerly aspect calculated to receive the maximum amount of insolation available. Hence, screen readings from this station are not strictly comparable with those of the two preceding stations where the screen was on grass. Synchronous readings were taken at irregular intervals during the day and occasionally at night (rarely more than five per diem) of the wet and dry bulb in the screen, of a grass minimum thermometer placed one inch above the soil of the bed, and of an earth thermometer placed in an iron tube lying horizontally one inch below the surface of the soil. The last two mentioned readings were expected to give respectively an approximate value of the actual temperature to which the visible portions of the plants were exposed and that of the soil surrounding their roots. Other columns in the record gave details of the time of occurrence, duration and nature of any precipitation within twelve hours subsequent to each observation.

During the spring and summer of 1924, observations were usually restricted to occasions when precipitation was anticipated. The blue-flowered variety of the pimpernel was at this time added to the list.

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Table I. gives a summary of an analysis of those features that can be recorded conveniently in tabular form. Further information and notes explanatory to the table will be found under the sections dealing with the several plants. In columns 7 and 8 the times of opening and closing represent the earliest and latest times that the flowers (or leaves) were observed fully open during days of rainless weather. Columns 9 to 14 include only those observations made between the normal times of opening and closing as indicated in Columns 7 and 8.

I.—Scarlet Pimpernel (*Anagallis arvensis*).

Gerard (1) claimed that the closing of the flowers of this plant "betokeneth rain and foul weather; contrariwise, if they be spread abroad, fair weather." Inwards (8) records several items of folk lore in the same sense.

Moreau (10) mentions an opposite effect, *i.e.*, that the flower expands on the approach of rain, but he omits to say if this information is the result of his own observations.

It is now proposed to summarize the results of analysis of 247 observations on this flower. It has not been observed open at night. The diurnal duration of the flower's expansion is restricted to 8-9 hours even in the long midsummer days.

The records clearly point to relative humidity as a controlling factor in the irregular movements during the day. The critical value is approximately 80[1] per cent., *i.e.*, when the humidity was above this value the flower was never recorded fully open. An experiment in which the temperature of the air surrounding the flower was reduced, and the relative humidity thereby increased, lends support to this inference.

Temperature of the soil about the roots of the plant is a doubtful factor: for as that temperature never fell below 59° F. in the restricted day period whilst the plant was under observation, it could hardly be expected that a critical minimum would be revealed even if one existed.

The intensity and nature of the light appears negligible. No variation in temperature, humidity, dew-point or state of sky appears to be able to prevent the close of the flower at its usual time in the afternoon; and as the movement takes place under full sunshine (in the midsummer), diminution in the intensity of light can have no influence.

The uncertain behaviour of the flower during precipitation as summarized in Columns 9 and 10 of Table I. is explicable when the relative humidity is taken into account. In all cases in which the flower was recorded open, the relative humidity was below the critical value—and the reverse is equally true for all instances in which the opposite state was recorded. In short, precipitation, *per se*, does not induce the closing movement.

II.—Common Daisy (*Bellis perennis*).

An article under this head in the *Encyclopædia Britannica* (6)

[1] As measured in the screen at 4ft. above the surface, and, therefore not an accurate value for the air surrounding the plant during calm weather.

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TABLE I.—Summary of Observations on Certain Plants in Relation to Weather Changes.

PLANT.	Number of Observations at					Normal Time of		Observations coincident with precipitation.		Observations followed by precipitation within 3 hours.		Observations followed by precipitation within 3 to 6 hours.	
	Howden.	Stamford Hill.	Finchley.	Total.	Night.	Opening in hours and minutes after sunrise.	Closing in hours and minutes before sunset.	Times open	Times shut.	Times open.	Times shut.	Times open.	Times shut.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Scarlet Pimpernel (*Anagallis arvensis*) ...	114	...	133	247	8	4.15	3.20	7	12	7	9	7	3
Common Daisy (*Bellis perennis*)	19	...	199	218	14	3.40	2.—	11	21	9	9	4	1
Common Chickweed (*Stellaria media*) ...	...	77	205	282	20	3.30	2.15	9	19	11	6	4	1
White Clover (*Trifolium repens*)	90	66	1	157	8	0	0.45	9	1	...	...	...	...
Dandelion (*Taraxacum officinale*)	44	38	155	237	15	2.20	2.30	16	18	...	...	...	...
Gentian (*Gentiana Pneumonanthe*)	...	...	40	40	...	...	...	2	7	4	2	4	0
Common Marigold (*Calendula pluvialis*) ...	...	...	55	55	6	...	...	6	1	2	...	3	...
Blue Pimpernel (*Anagallis arvensis var cærulea*)	...	...	17	17	...	...	...	1	...	2	...	1	...

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states that "this flower rolls up its florets on the approach of rain and unfolds them once more on the return of bright weather."

No exceptions to its nocturnal sleep have been noted. No correlation between flower movement and light intensity or cloudiness is apparent from either observations or experiments.

Relative humidity is a controlling factor, the movement occurring between 64 and 82 per cent. of saturation.

Soil temperature exercises some influence, but whether this be secondary in so far as it affects the relative humidity is uncertain. The approximate critical value is 52° F. and for surface readings 58° F.

Temperature control experiments in the direction of inducing the flower to close during the day were inconclusive, but others conducted at night to induce an opposite effect were successful in showing a response to the radiant heat of a coal-fire and also to that of a gas-filled electric lamp. As in these experiments no attempt was made to increase the water-vapour content of the air in proportion to its rise in temperature, the low relative humidity caused thereby may be the *vera causa* of the movement. For instance, in one experiment the initial air temperature of 50° F. was increased to 85° F. Assuming the air to have been saturated at the lower temperature, the final relative humidity could not have exceeded 35 per cent.

A solitary instance when the flower apparently acted up to its reputation was observed on May 9 at 15.30 G.M.T., when the flower was shut at a surface temperature of 70° F., relative humidity 54 per cent., sky one-tenth clouded. A passing shower fell one hour later.

The results recorded in Columns 9 and 10, Table I., appear to justify the reputation of the flower to some extent: but when the individual cases are investigated in relation to the two controlling factors, temperature and relative humidity, it is obvious that in every case one of these two elements would have determined the observed state without the coincidence of precipitation.

III.—Common Chickweed (*Stellaria media*).

Taylor (2) asserts that when the flower of this plant expands boldly and fully, no rain will happen for four hours and upwards; if half-open, the weather will be showery; whilst if shut, heavy rain will ensue.

Inwards (8) records that the plant "expands its leaves boldly and fully when fine weather is to follow; but, if it should shut up, then the traveller is to put on his great coat." He also relates that the half-opening of its flowers is a sign that the wet will not last long; and further, that if the flowers keep open all night, the weather will be wet next day.

Observations on this plant have been confined to the behaviour of the flower. Of those made at night, the flower was always found shut except on September 29 at 25 minutes after sunset. According to weather lore above cited, the next day should have been wet. It happened to be quite fine. Conditions at the time do not explain this exception, viz., cloudless sky, wind force 2, dry bulb 61°, wet 55°, grass temperature 57°—all appear quite normal.

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The temperature of the soil surrounding the roots and that of the air surrounding the plant are controlling factors in the flower movement. The critical value for the former is 50° F., that of the latter 1° higher. Above these temperatures, relative humidity becomes the dominant factor of control during the day, the closing movement taking place between 71 and 82 per cent. as recorded in the screen. The critical value for individual observations shows a steady increase between these two limiting percentages coincident with seasonal air temperature increase during the spring and early summer.

Observations coincident with precipitation (Columns 9 and 10, Table I.) suggest a definite correlation between the petal movements and this element. Investigation of individual cases shows that this is no more real than in the case of the daisy, the cause in nearly every instance being referable to one or other of the two controlling factors indicated above.

IV.—White or Dutch Clover (*Trifolium repens*).

To Pliny must be given priority for the claim that this plant indicates the approach of bad weather, as he affirmed that when clover-grass looks rough and its leaves stand staring up, it is a sign of a tempest.

Inwards quotes that "clover contracts its leaves at the approach of a storm." The former obviously referred to high wind, but the use of a term so ill-defined as "storm" in the latter quotation renders its meaning vague.

W. J. Humphreys, in a letter to the writer, mentions that he has often seen the leaves of ordinary red clover change their attitude a short time before the oncoming of a shower. Red clover was not included in the observations.

Observations were confined to the leaves of this plant. Two exceptions to its nocturnal sleep were noted:—

(1) 25 minutes after sunset on the same occasion referred to under the chickweed section.

(2) December 10, at 19.45 G.M.T., in a dense wet fog at an air temperature of 41° F. The occasion was remarkable as similar conditions had prevailed without interruption for the past 28 hours.

As in nine out of ten instances, the leaves were found open at the time of precipitation, it is apparent that the leaf movement can give no indication of wet weather.

It was a surprise to discover from the analysis of the observations that neither temperature, relative humidity nor light appeared to exercise any influence on the irregular day movements; and these negative conclusions were confirmed by a series of simple control experiments.

Apart from the regular diurnal movements, it is the wind velocity that is the cause of the movement during the day. When a velocity below 20 m.p.h. in gusts is recorded at the height of a Dines pressure tube anemometer (42 feet) the leaves are always found open. Above 20 m.p.h. as the velocity increases the leaves gradually approach until when gale force is reached they are

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completely shut. The movement, however, in no case preceded the increase in velocity and is therefore valueless for prediction of high wind. This effect was first suspected when, with a wind attaining 28 m.p.h. in squalls, leaves of plants exposed to the wind were half-shut, whilst those in sheltered positions were wide open.

V.—Dandelion (*Taraxacum officinale*).

Both composite flower and the pappus or down are reputed to foretell the weather.

Inwards (8) records a saying to the effect that the dandelions close their blossoms before a storm. Unfortunately the definition of "storm" is rather loose, so that one is left in the dark as to whether this refers to wind, rain or thunderstorm.

He also quotes from Coles, "that if the down fly off this plant and the coltsfoot and thistle when there is no wind, it is a signe of rain," and also, "that when the down contracts, it is a sign of rain."

The behaviour of the down has not been investigated, but it seems probable that vertical currents ascending beneath a thundercloud would cause the down to fly off in an apparent calm.

In correspondence with the writer, W. J. Humphreys mentions that he has often noticed that the flower while in its golden stage closes up with the approach of rain, "no doubt in response, mainly, if not wholly, to change of humidity," but only shortly before the onset of the rain.

Observations of the flower movement were made during the months of April to June inclusive at Finchley, and from August to October at Stamford Hill.

The figures do not give any indication that the flower justifies its reputation as regards rain.

No correlation could be traced between the relative humidity and flower movement during the usual diurnal period of expansion of the flower; nor is there any very definite connection with the temperature of the soil one inch below the surface. All that can be stated is that the flower was not observed shut at values above 51° F., although it was found open below that value on several occasions. The depth to which the roots penetrate may account for these exceptions.

An examination of the surface temperature reveals a critical period between 46° and 51° F.—the flower was always recorded shut below the lower value and always open above the higher.

The velocity of the wind does not appear to influence the movement in the slightest degree.

VI.—Gentian (*Gentiana Pneumonanthe*).

The following quotation from Inwards (8) is the only reference to the behaviour of this plant relative to the weather:—"The gentian (*G. Pneumonanthe*) closes up both flowers and leaves before rain."

The plant is rather difficult to cultivate in the polluted air in the vicinity of London. Hence the small number of observations which are not sufficiently numerous to induce the exact times of

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the normal diurnal movements, nor to decide how the flower behaves before wet weather. A negative result is, however, foreshadowed. The petals appear to be susceptible to the incidence of precipitation, as in only two out of nine instances was the flower found open when rain had begun to fall. In the first exception a passing shower of but twenty minutes' duration was recorded; in the second, drizzle only was falling which later changed to rain, by which time, however, the flower had responded by closing up.

VII.—Common Marigold (*Calendula pluvialis*).

Inwards (8) records that "if the flower should open at six or seven in the morning and not close till four in the afternoon, we may reckon on settled weather."

Observations were unfortunately confined to the month of August and were too few to make accurate inductions therefrom.

Reference to the figures in Columns 9 and 10 of Table I. does not inspire confidence in the plant's ability to forecast rain. It is, however, noteworthy, that in all six instances in which the flower was observed open whilst rain was falling the relative humidity was below 83 per cent., and in three of them below 70 per cent. In the one instance where it was found shut after rain the value was 97 per cent. This is suggestive of a correlation between the flower movement and that element, but, as during the short period of observation, the relative humidity was never again above 83 per cent. during the day, the clue could not be followed up.

Attempts to correlate either surface or soil temperatures with its movements proved equally abortive for the same reason.

VIII.—Blue Pimpernel (*Anagallis arvensis var. cærulea*).

A small number of observations were made upon this variety of pimpernel during August. According to Sowerby (4) it shares the weatherwise reputation of the more common scarlet variety. It would seem to respond in a similar manner to the latter with one exception, and that is with regard to the times of the regular diurnal movements near sunrise and set. The flower opens about half an hour before, and closes about the same interval later than the scarlet pimpernel. It is suggested—tentatively—that the colour of the flower is the cause of this difference. Assuming that direct solar radiation provides the necessary stimulus for the opening movement, less should be required to raise the temperature of a blue than of a red surface.

Conclusions.

Not one of the plants investigated above has justified its reputation to predict with certainty local weather changes. The irregular movements during the day are due to changes in the various meteorological elements, and at best are but synchronous with the latter whilst in many cases there is definite lag.

Temperature at the surface of the soil appears to be a controlling factor in the movements of daisy, chickweed and dandelion, although not well defined. The daisy and chickweed respond more precisely to the temperature of the soil about their roots.

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Above the critical temperature the daisy and chickweed definitely respond to change in relative humidity, 82 per cent. being the critical maximum in each case. The scarlet pimpernel likewise appears definitely sensitive to a value of 80 per cent. The values are approximate as the hygrometric readings are those for the air four feet above the plants. The approximate common value for three plants, distinct in many respects, is remarkable. As to whether this element operates by controlling the rate of evaporation from the surfaces of the bracts or by some other means, it must be left for the plant-physiologist to determine.

Daisy, chickweed and pimpernel would therefore justify their reputations to forecast rain to the extent of the number of hours that elapse between the prerequisite humidity increase and the incidence of precipitation (assuming the air temperature to be above the critical minimum). Unfortunately there are many exceptions to this sequence of changes, whilst humidity frequently increases to saturation without rain as an immediate sequel.

Wind velocity as the control factor in the irregular day leaf movements of clover may be merely a mechanical effect, the leaves being forced into positions offering the least resistance to the air movement.

The results indicate that the uncertain response of the plants to the incidence of precipitation can be explained by coincident humidity or temperature changes.

The diurnal movements morning and evening are best described as regular habits, and do not appear to be subject to the weather conditions of the moment in the same degree as do the erratic movements under investigation.

In conclusion, the writer desires to acknowledge his grateful appreciation of the loan of screen and thermometers by the Council of the Society.

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DISCUSSION.

Mr. BONACINA asked to be allowed to draw attention to the differences between these floral indications and those chromatic indications of Miss Stevens's. He wished to point out that in the latter work you were totalising the effect of every layer of the atmosphere, whereas in Mr. Silvester's case you are dealing only with the surface conditions, and would not expect these floral indications to be much good in weather forecasting. There were many different kinds and qualities of rain, and at the surface the differences of humidity before rain were very great. Sometimes the lower layers are quite dry before, and even during rain, and so he did not think there could be much indication of coming weather. The author of the paper appears to have paid no attention to the well-known case of the leaf of the white poplar, which has a downy under-surface and is supposed to show the white side before rain. He thought that it was one of the most famous cases, but he had never attempted to test it.

Mr. J. E. CLARK, unable to stay for the discussion, had asked him to draw attention to the effect of wind in closing the stomata of plants, and thus by checking transpiration lessening the drying effect of wind.

Mr. N. L. SILVESTER, in reply, to Mr. Bonacina, said that he had not included the leaves of the white poplar among the observations. He suggested that the pale under-surfaces of the leaves of this tree were rendered visible by the upward vertical component in the air movement that one associated with the oncoming of rain. As to Mr. Bonacina's criticism of the usefulness of his data, he must add that when he started the observations he was doubtful about obtaining positive results. The negative results of the first stage of his work had proved of great interest to him in that they had stimulated him to probe a little into the plant world and learn something about it.

Tables of Averages and Extremes for Gibraltar and Malta.

From time to time in the past climatological tables relating to various parts of the British Empire have been published in the *Quarterly Journal*. These tables provide a great amount of material which is not readily available in any other form, and should be of considerable value to students of climatology.

Tables of averages and extremes for Gibraltar and Malta have recently been compiled at the Meteorological Office, under the supervision of Mr. C. E. P. Brooks, in connexion with the revision of the Mediterranean Pilot, and as these include, for many elements, averages extending over a long period of years, it is thought that they may be of interest to Fellows. The table for Gibraltar is based entirely on manuscript records, mainly compiled by the Royal Army Medical Corps, and preserved in the Meteorological Office. The table for Malta is based on a number of different sources, including the Reports of the Army Medical Department and the tables compiled by Professor Agius of the University of Valetta and published in the Blue Books.

Both stations come within the typical Mediterranean climatic province, with mild, rather rainy winters and hot dry summers, but at Gibraltar the period of almost rainless weather is less prolonged than at Malta. A comparison of the two tables indicates that apart from the rainfall there is comparatively little difference between the climates of the two places. Malta has higher minimum temperatures, and occasional very hot days in summer which Gibraltar largely escapes. The preponderance of east and west winds at Gibraltar is due to the configuration of the land; the site at Malta is sufficiently open, and the predominance of winds from north-west is due to the stable pressure distribution.

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TABLE I.—Meteorological Table for Gibraltar (Lat. 36° 6′ N. Long. 5° 21′ W. Height Above Mean Sea-Level = 53 Ft.) Compiled from 15-71 Years' Observations, 1852-1923.

Month.	Pressure At Mean Sea Level, reduced to 32° F. and Lat. 45°	Air Temperature.							Relative Humidity.	Cloud Amount Scale 0 to 10.	Rain.			Wind.										No. of Days Gales.	No. of Days Fogs.
	Mean For Month.	Mean ‡	Mean Daily Max.	Mean Daily Min.	Mean Highest in each month.	Mean Lowest in each month.	Mean. Absolute Highest Recorded.	Mean. Absolute Lowest Recorded.			Mean Fall.	No. of Days. §	Max. Fall in 24 hrs.†	Mean Force. Beaufort Scale.	Percentage of Observations, from N.	N.E.	E.	S.E.	S.	S.W	W.	N.W.	Calm		
	mb.	°F	°F	°F	°F	°F	°F	°F	%		mm.		mm.												
January	1021	55	61	49	67	41	75	33	77	4.5	129	10	109	3.6	1	1	29	7	1	4	26	27	4	1	0.3
February	1020	56	62	50	69	43	81	33	77	4.9	107	10	109	3.8	0	1	30	10	1	5	28	22	3	1	0.1
March	1017	57	63	51	71	44	78	37	77	4.9	122	11	108	3.7	1	1	25	8	1	7	32	23	2	1	0.3
April	1017	61	67	54	76	48	87	43	75	4.0	68	9	165	3.5	0	1	26	10	1	6	29	24	3	0.3	0.1
May	1016	65	72	58	81	53	89	46	73	3.8	44	6	50	3.2	0	1	33	9	2	5	31	16	3	0.3	0.1
June	1018	70	78	63	87	57	97	49	71	2.7	12	2	45	3.3	0	1	34	11	3	5	25	18	3	0.1	0
July	1017	73	82	67	90	62	100	55	72	2.2	1	0.5	11	3.2	0	1	40	9	2	5	25	14	4	0.1	0.3
August	1017	75	83	69	91	63	100	57	72	2.6	3	1	43	3.1	0	1	44	8	3	4	24	12	4	0.0	0.3
September	1017	72	79	66	87	59	95	50	75	4.0	35	4	145	3.0	0	1	46	7	2	5	24	10	5	0.1	0.1
October	1017	66	72	60	81	52	95	44	77	4.4	84	8	138	3.0	1	1	37	7	2	9	23	16	4	0.2	0.2
November	1018	60	66	54	73	47	79	35	79	4.9	162	11	165	3.4	0	1	34	6	1	5	29	20	4	0.9	0.1
December	1020	56	62	50	69	42	77	30	78	4.3	142	11	175	3.4	2	1	25	6	1	4	29	27	5	1	0.1
Means	1018	64	71	57	93*	39*	—	—	75	3.9	—	—	—	3.3	0	1	34	8	2	5	27	19	4	—	—
Totals	—	—	—	—	—	—	—	—	—	—	900	84	—	—	—	—	—	—	—	—	—	—	—	7	2
Extreme Values	—	—	—	—	—	—	100	30	—	—	—	—	109	—	—	—	—	—	—	—	—	—	—	—	—
No. of Years' Observations	65-67	64-68	48	48	56-60	54-61	58-60	58-61	15-16	15-16	65-68	68-71	68	15-16					15-16					32-39	42

Hours of observation 7, 13, 21 hours G.M.T.
‡ [7+13+ (2×21)]
* Mean of highest each year and lowest each year.
† Maximum Fall during the 24 hours from one morning observation to the next.
§ Day with 0.3 mm. or more rain.

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TABLE II.—METEOROLOGICAL TABLE FOR MALTA (LAT. 35° 54′ N. LONG. 14° 31′ E. HEIGHT ABOVE MEAN SEA-LEVEL—185FT.) COMPILED FROM 9-71 YEARS' OBSERVATIONS, 1852-1923.

Month.	Pressure at Mean Sea Level reduced to 32° F. and Lat. 45°.	Air Temperature.							‡Relative Humidity.	‡Cloud Amount. Scale 0 to 10.	Rain.			Wind.										No. of Days Gales.§	No. of Days Fogs.
		Mean.	Mean.		Mean.		Mean.							Mean Velocity.‡	Percentage of Observations, from										
	‡Mean for Month.	‡	Daily Max.	Daily Min.	Highest in each month.	Lowest in each month	Absolute Highest Recorded.	Absolute Lowest Recorded.			Mean Fall.	No. of Days.	Max. Fall in 24 hours.†		N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm		
	mb.	°F	°F.	°F.	°F	°F	°F	°F	%		mm.		mm.	mi./hr.											
January	1017	53	59	51	65	44	76	39	77	5.5	82	13	60	11	6	14	6	11	3	14	11	27	8	0.8	0.6
February	1016	53	60	51	66	44	73	34	77	5.2	56	10	79	11	5	14	6	11	4	12	11	29	8	0.3	0.2
March	1014	55	62	52	71	45	83	37	75	4.8	38	8	73	11	4	12	5	14	5	10	11	30	9	0.1	0.4
April	1013	59	66	56	75	49	93	44	75	4.5	22	5	43	11	6	12	8	15	4	8	10	30	7	0	0.1
May	1014	64	71	61	81	54	80	49	73	3.9	10	3	39	9	9	16	9	15	3	5	6	28	9	0.2	0.2
June	1015	71	79	67	88	61	98	58	70	2.5	2	1	19	9	8	19	8	12	3	4	6	31	9	0	0.2
July	1015	77	84	72	95	67	104	62	66	1.2	1	0.2	16	7	11	20	4	7	2	4	5	35	12	0.1	0.2
August	1015	77	85	73	93	68	105	62	68	1.6	3	0.7	31	7	9	19	5	9	2	5	5	32	14	0.1	0.2
September	1016	74	81	71	90	64	100	57	71	3.1	32	3	123	8	7	17	7	16	4	8	4	26	11	0	0.1
October	1016	69	76	66	85	58	94	45	73	4.7	73	7	204	8	4	15	6	19	5	9	7	25	10	0.1	0.6
November	1016	62	68	59	76	51	82	42	75	5.2	91	11	184	9	4	15	5	14	6	11	9	27	9	0	0.6
December	1016	56	62	54	69	46	75	39	78	5.6	94	14	197	10	4	12	4	11	3	14	12	29	11	0.4	0.6
Means	1015	64	71	61	97*	42*	—	—	73	4.0	—	—	—	9	6	15	6	13	4	9	8	29	10	—	—
Totals	—	—	—	—	—	—	—	—	—	—	504	77	—	—	—	—	—	—	—	—	—	—	—	2	4
Extreme Values	—	—	—	—	—	—	105	34	—	—	—	—	294	—	—	—	—	—	—	—	—	—	—	—	—
No. of Years Observations.	65-67	62-63	61-65		63-65				62-66	65-67	64-65	65-67	64-66	37-41					62-64					9	35

Observations at 8 hours Local Time.
‡ Adjusted to mean of 24 hours.
* Mean of highest each year and lowest each year.
† Maximum Fall during the 24 hours from one morning observation to the next.
§ Wind speed Force 8 or over.

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THE MARSHAM PHENOLOGICAL RECORD IN NORFOLK, 1736-1925, AND SOME OTHERS.

By IVAN D. MARGARY, M.A.

[Received November 3—Read December 16, 1925.]

I.—Introduction.

A valuable addition to phenological records has recently been brought to light by the discovery of a record, kept by five generations of the same family near Norwich, giving a very complete series of observations of plant and bird dates for a period covering 190 years.

Such continuity must surely constitute an unique record for private observing (apart from institutions) in this or any other branch of science, but seeing that this record was only discovered by the merest chance, it seems possible that other valuable and unknown records are also available. It is to be hoped that anyone knowing of other records of such length will take steps to report them, so that the patient work of the old observers may not be wasted. The investigation of this record has been a work of great interest.

The finding of the record (briefly noted in the Phenological Report for 1924[1]) was due to the discovery by Mr. R. A. Fraser of an old summary hidden under the floor of the Old Mill, Ramsbury, Wilts. He reported this to the Editor of the *Fly-Fishers' Club Journal*, with whom the Phenological Committee had been in correspondence, and the news was then most kindly passed to them by the Editor. Subsequent investigation, in which Mr. A. W. Preston, F.R.Met.Soc., of Norwich, rendered invaluable help, revealed two remarkable points. First, that the records were still being kept by the same family, and secondly, that Mr. Preston had reported the existence of the record to the Phenological Committee in 1900, and had afterwards supplied yearly the few observations relevant to the Society's phenological schedule.

They appeared first in the Report for 1900, but without any special comment, perhaps because the remainder of the record was not then thought appropriate, and the present Committee were quite unaware of the treasure that lay hidden behind those few records entered against Hevingham in the Reports.

List of Observers.

Robert Marsham, F.R.S.	observed	from	1736	till	1797
Robert Marsham, Son, ...	,,	,,	1798	,,	1810
Robert Marsham, Grandson	,,	,,	1836	,,	1855
Rev. H. P. Marsham, Great Grandson	,,	,,	1856	,,	1892
Major H. S. Marsham, Great Great Grandson	,,	,,	1893	,,	now

The present observer, Major Marsham, and his son, Rev. A. F. Marsham, were extremely kind in placing all their data at the

[1] *Q.J.R. Meteor. Soc.*, **51**, 1925, p. 295

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Society's disposal, and supplied copies of the second part of the record, a heavy task in itself.

The observations down to 1788 were published in full in the Royal Society's *Philosophical Transactions*,[2] but without any discussion. Subsequently they were discussed in two papers by the late Mr. T. Southwell, F.Z.S.,[3] but only summaries of extremes and averages were given. A brief reference to the first part of the record is also given in the *Natural History Journal*[4] as a quotation from the *Penny Magazine* of 1834. No other work appears to have been done on them, and the full series has not been published since 1788. Southwell deals chiefly with the abnormal years and describes the diaries, with full extracts for certain interesting seasons. The first observer, Robert Marsham, kept a valuable general weather diary, but unfortunately this diary and the records of his son (*i.e.*, the originals down to 1810), are at present missing. I was able, through Mr. Preston, to get in touch with Miss Southwell, who still had all her father's papers on the Marsham record, including a full copy of the phenological series, which, being compiled from the original diaries now missing, afforded a useful and quite satisfactory check upon the accuracy of the Royal Society's table. These she most kindly presented to me, and so preserved a further 22 years of the record (1789-1810) which would otherwise have been lost.

The observations were made on the estate around Stratton Strawless Hall (lat. 52° 43′ N., long. 1° 16′ E.), about seven miles north of Norwich and 12 miles from the coast at the nearest point. From 1858 to the present time they have been kept at Rippon Hall, only 1½ miles north of Stratton. The locality is fairly high and open, the altitude of Stratton being 90ft., and there is a gradual slope towards the south from Rippon Hall. The soil is mostly very light and sandy with a gravel subsoil.

It will be seen from Table I. that 27 phenomena were regularly observed; the leafing of 13 trees, four flowering events, and the movements of eight migrant and other birds, besides the appearance of the yellow butterfly and the croaking of frogs. Some of these were not recorded during certain periods, and only a few commenced before 1745. From 1760 to 1770 the observer was frequently absent from home, and some of the observations were made in other parts of the Home Counties, mainly north of London, but for lack of better data it has been thought well to include them in the table. After 1775 the records refer strictly to the home locality. No records were kept between 1811 and 1835 inclusive, nor in 1841-44. Some observations for 1850-54 appear in Southwell's copy of the record which do not appear in the original notebook. That they are of true Marsham origin seems indicated by the inclusion of such characteristic observations as turnip, young rooks, etc., and they have therefore been shown in Table I. in square brackets. From 1855 the record is continuous to the present time.

The extraordinary continuity of many of the records is illustrated by the following, showing the number of blanks in the years

[2] *Phil. Trans.*, **79**, Part 2, 1789, p. 154.
[3] *Norfolk and Norwich Naturalists' Society Trans.*, **2**, 1874-5 p. 31. *Ib.*, **7**, 1901, p. 246.
[4] *Nat. Hist. J.*, **20**, 1896, p. 68.

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1759-1925 (omitting the years 1811-34 and 1841-4), 140 effective years in all:—

Hawthorn leaf and horse chestnut, four each, snowdrop, oak and beech, six each, lime eight. Cuckoo one, swallow six, rooks build eight.

All dates down to 1752 have been corrected from the Old Style Calendar by the addition of 11 days.

The same methods of observation have been carefully followed by the successive observers. In the case of plants, the *first* tree or plant on the estate to leaf or flower was noted. This is in accordance with Continental practice, though this Society recommends observers to keep to the *same* specimen each year. Nevertheless, the agreement with the Society's series of dates since 1891 is remarkably good. Leafing was taken to be the date when the leaves were of recognisable shape, and flowering when the centre of a blossom was visible. As to the birds, the first singing of the thrush was noted at any time of the winter, not only after January 1st, as is the Society's method. Until 1915 the column headed "Ringdoves coo" evidently refers to any pigeon. Since then it has been strictly confined to the turtle dove. A few very early dates of the yellow butterfly are no doubt simply due to hibernated specimens, the March and April dates being those of the real emergence, but all have been given in the table.

Southwell's two papers give a very full discussion of the extreme dates in each series, the second paper being an addendum to carry the first on from 1876 to 1900. The extremes for the full period to 1925 are now given at the end of Table I., and no further reference to them need be made here except to remark that since 1900 three new early and seven new late "records" have been established, and that the extremes are quite irregularly distributed throughout the period of observation. The averages will be dealt with later for reasons that will then be apparent.

Southwell's papers are extremely interesting for the general weather notes extracted from Robert Marsham's diary on some very remarkable years; the reader should bear in mind that any dates given there prior to 1753 have *not* been corrected for the Old Style Calendar.

II.—Comparison with the Society's Series.

The greatest value of the record, from the Society's point of view, lies in the opportunity given for comparison with the results tabulated in its annual Phenological Reports. These Reports contain valuable series of comparative data for the past 34 years, and it seemed improbable that any satisfactory means would be found for extending the series back to earlier years. It will now be shown that the Marsham observations provide a reliable basis for extrapolating the Society's series right back to 1745.

Observations of a single plant are of necessity erratic, and to obtain reliable comparisons it is preferable to take the mean of several plants. Accordingly, a group of seven of the Marsham plants was chosen. These were: Snowdrop flowering, birch, oak, beech, horse chestnut and lime leafing, and hawthorn flowering, and they were chosen mainly on account of their continuity in the earlier years, the series being available back to 1745.

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TABLE I.—THE

EXPLANATION OF DATE NUMBERS.

Ordinary Years.			Leap Years.		
-31— -1=Dec.	91—120=April.	213—243=Aug.	-31— -1=Dec.	92—121=April.	214—2
1— 31=Jan.	121—151=May.	244—273=Sept.	1— 31=Jan.	122—152=May.	215—2
32— 59=Feb.	152—181=June.	274—304=Oct.	32— 60=Feb.	153—182=June.	275—30
60— 90=March.	182—212=July.	305—334=Nov.	61— 91=March.	183—213=July.	306—33

YEAR.	PLANTS.												
		FLOWERING.				LEAFING.							
	*Mean of 7 plants.	Snowdrop.	Wood Anemone.	Hawthorn.	Turnip.	Hawthorn.	Sycamore.	Birch.	Elm (Common).	Mountain Ash.	Oak.	Beech.	Horse-Chestnut.
1736	...	...	...	...	...	...	...	...	...	...	...	...	...
1738	...	...	...	†	...	...	...	...	...	...	...	...	...
1739	...	...	...	...	63	65	65	...	...	...	...	...	...
1740	...	...	...	160	134	106	116	...	...	...	...	...	...
1741	...	...	...	140	...	...	...	...	...	...	...	...	...
1742	...	...	...	146	116	...	...	...	...	...	...	...	...
1743	...	...	...	139	93	...	...	...	...	...	...	...	...
1744	...	...	...	E144	110	99	101	...	...	...	...	...	...
1745	106	17	...	144	109	96	99	99	...	...	*121*	*126*	99
1746	113	31	...	144	117	96	111	111	...	...	132	132	*107*
1747	104	19	...	127	88	57	95	99	...	...	124	127	*98*
1748	113	16	...	M154	124	105	116	112	...	...	*129*	*132*	*108*
1749	102	15	...	M132	79	61	88	94	...	...	123	123	*96*
1750	89	26	...	114	64	55	64	63	...	...	101	116	*85*
1751	101	20	...	140	99	80	...	92	76	...	126	125	91
1752	104	*25*	...	146	108	M 61	108	104	...	...	122	122	*90*
1753	97	32	...	131	89	80	93	86	...	...	114	119	*91*
1754	106	18	...	142	129	97	104	104	...	...	131	*127*	*102*
1755	94	26	...	130	105	90	90	91	100	99	108	111	*90*
1756	101	8	...	146	64	57	92	71	90	96	128	128	*99*
1757	101	37	..	139	101	79	91	88	91	90	116	119	*94*
1758	98	9	...	133	104	78	91	91	91	103	119	117	103
1759	91	9	...	126	58	42	M 81	M 90	M 78	91	105	115	M 84
1760	105	24	...	118	104	K 67	94	93	100	93	110	110	103
1761	88	*16*	88	124	15	S 58	84	83	S 58	84	104	110	*88*
1762	95	12	...	124	109	S 66	M106	96	M102	109	112	111	M106
1763	88	*9*	...	127	107	S 57	87	84	91	87	114	110	S 60
1764	95	6	...	M138	M 78	48	...	*92*	L 81	S 90	H115	H115	S 90
1765	94	5	83	K131	...	75	M 97	*90*	M 88	...	H121	H121	M 90
1766	94	*14*	...	*130*	...	75	S103	70	M102	S122	S122	*115*	S103
1767	102	28	...	149	...	S 71	S100	S100	M 73	...	E123	125	M 98
1768	97	28	...	132	88	59	83	81	95	95	115	115	95
1769	94	13	...	E124	...	E 63	M107	*90*	K 84	M 90	K115	*115*	M 96
1770	109	21	...	142	113	S 70	M113	121	M 70	121	131	126	M 98
1771	116	27	101	145	123	101	124	124	M114	122	135	130	122
1772	104	14	...	143	108	82	M104	*97*	M 99	M104	134	124	M104
1773	96	11	98	126	83	80	100	88	96	96	113	119	106
1774	89	28	85	130	96	H 63	93	90	93	90	115	114	98
1775	88	14	68	121	74	57	84	79	78	80	111	115	80
1776	86	— 2	94	119	98	H 68	86	79	79	83	106	110	90
1777	92	17	...	126	97	79	87	85	97	88	112	112	80
1778	98	26	95	H134	104	94	96	96	102	97	120	105	101
1779	74	— 8	74	100	50	53	66	63	63	64	90	95	84
1780	95	40	80	131	121	75	85	88	86	88	117	115	82

* Mean of snowdrop and hawthorn flowering, birch, oak, beech, horse-chestnut and lime leafing.

† Hawthorn flower 104 at Nismes, France; and swallow 79 at Piacenza, Italy (not included in the means).

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PHENOLOGICAL OBSERVATIONS.

Dates in *italics* are values interpolated for obtaining the annual means of the seven plants. They are not included in the means of the separate plants. Dates in square brackets (see p. 28) are included as regular observations in the means.

				BIRDS.										
				MIGRATION.				OTHERS.						
Hornbeam.	Ash.	Lime.	Maple.	Swallow.	Cuckoo.	Nightingale.	‡Churn Owl Calls.	Thrush Sings.	§"Ringdoves" Coo.	Rooks Build.	Young Rooks.	Yellow Butterfly Appears.	Frogs and Toads Croak.	YEAR.
								(1735)						
...	...	...	...	101	...	...	...	−17	...	...	...	...	...	1736
...	...	...	...	†	...	...	...	...	...	...	...	...	...	1738
...	...	...	...	114	120	126	...	...	...	...	...	...	...	1739
...	...	...	...	102	116	134	153	69	...	69	...	...	...	1740
...	...	...	...	110	120	115	...	...	44	55	103	...	82	1741
...	...	...	...	118	118	122	...	42	...	...	102	...	112	1742
...	...	...	...	113	118	121	...	42	...	...	...	...	70	1743
...	...	...	...	102	122	111	155	...	...	63	103	...	99	1744
...	...	*133*	...	104	123	113	141	37	14	78	109	...	84	1745
...	...	132	...	109	117	120	136	...	...	67	101	...	85	1746
...	...	*131*	...	103	123	116	140	25	24	55	96	...	66	1747
...	...	*137*	...	104	118	125	160	40	50	71	105	...	99	1748
...	...	*129*	...	106	114	117	151	28	55	60	99	...	75	1749
...	...	*118*	...	109	112	110	148	28	33	55	100	51	62	1750
...	117	*115*	...	*108*	120	117	134	13	9	73	108	...	97	1751
...	...	*117*	...	104	111	109	144	41	7	...	100	...	80	1752
...	131	*109*	...	107	114	109	...	32	53	62	105	...	91	1753
...	...	*120*	...	103	114	101	136	47	...	60	101	...	96	1754
103	112	102	108	96	113	104	155	47	63	73	108	...	91	1755
...	...	128	...	98	109	105	137	30	53	61	99	...	70	1756
...	121	*112*	...	106	116	106	137	47	69	72	108	...	88	1757
74	128	*113*	...	100	120	M113	138	33	62	64	103	74	75	1758
M 80	113	108	108	100	116	111	157	17	42	59	100	...	60	1759
104	110	110	104	102	112	112	150	41	...	M 72	102	...	75	1760
100	123	94	107	95	122	107	150	4	79	E 70	97	71	81	1761
H108	115	106	111	98	110	109	151	22	...	...	110	95	109	1762
93	127	105	...	95	117	110	151	L 42	...	...	106	...	89	1763
...	K126	*103*	...	L 99	H115	K123	...	9	53	66	...	...	...	1764
...	H121	M100	...	M104	M102	H123	155	42	56	66	...	...	82	1765
S122	S122	S102	...	M107	S122	S122	146	54	62	66	M114	65	68	1766
...	...	L 81	...	S113	127	E123	...	32	...	...	...	...	...	1767
110	118	111	...	108	115	108	...	...	...	60	101	...	77	1768
...	E124	L106	...	S109	K115	X143	161	...	...	...	...	...	...	1769
121	132	122	127	M113	121	126	...	28	...	54	...	45	...	1770
127	136	127	127	M108	125	123	140	52	57	74	...	49	96	1771
124	147	M109	126	K106	X117	132	138	43	63	50	...	85	85	1772
100	140	111	109	106	112	E140	153	26	62	62	100	62	77	1773
106	117	98	114	111	116	120	126	H 48	...	...	101	H 63	90	1774
C 90	122	C 90	H 97	F104	113	127	135	40	46	57	105	57	64	1775
93	114	103	97	99	112	108	147	52	45	73	93	82	82	1776
101	124	100	112	103	110	128	140	56	59	57	96	58	84	1777
102	115	*106*	103	111	120	125	147	40	40	64	102	77	78	1778
83	92	91	90	103	115	129	139	37	56	60	94	49	56	1779
80	122	93	113	113	113	...	121	47	68	61	97	68	81	1780

‡ Churn Owl=Nightjar.
§ Till 1915 these observations refer to *any* wood-pigeon.
Letters indicating observations made away from home:- C=Cambridgeshire, E=Essex, F=Suffolk, H=Hertfordshire, K=Kent, L=London, M=Middlesex, S=Surrey, X=Sussex.

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TABLE I.—T

Year.	PLANTS.													
		Flowering.				Leafing.								
	Mean of 7 Plants.	Snowdrop.	Wood Anemone.	Hawthorn.	Turnip.	Hawthorn.	Sycamore.	Birch.	Elm (Common).	Mountain Ash.	Oak.	Beech.	Horse. C
1781	91	29	85	118	97	68	81	83	85	83	109	105	100
1782	102	4	102	139	100	51	93	100	100	...	134	115	100
1783	92	26	91	117	82	54	97	91	92	91	114	109	*96*
1784	111	39	113	135	135	113	114	114	127	113	130	*122*	114
1785	102	24	106	122	117	102	109	108	109	108	125	113	109
1786	104	22	101	135	115	85	108	106	109	106	126	118	*108*
1787	90	30	75	121	81	56	81	77	77	76	116	115	80
1788	93	12	90	127	104	62	95	94	101	95	115	109	95
1789	103	25	105	129	130	89	106	107	111	106	127	115	*109*
1790	88	19	75	120	18	49	79	73	71	80	122	117	79
1791	87	16	77	128	56	64	80	82	77	81	105	105	81
1792	87	25	92	117	98	75	82	85	88	81	104	103	*81*
1793	95	15	93	131	93	61	84	84	95	95	125	117	82
1794	77	16	75	111	55	53	68	71	67	72	99	99	66
1795	101	41	100	131	131	98	105	106	112	106	119	*112*	*91*
1796	91	20	85	113	10	50	89	91	83	95	110	110	89
1797	94	22	90	138	97	69	93	90	96	90	117	110	83
1798	89	16	94	122	59	53	73	96	67	93	107	105	79
1799	112	23	110	153	...	90	105	111	78	111	140	*122*	111
1800	98	26	98	136	110	88	102	101*	100	100	112	107	97
1801	89	13	92	123	90	63	89	88	88	91	115	108	*78*
1802	91	36	95	118	100	78	87	92	84	88	112	107	82
1803	90	48	97	110	100	85	87	88	84	92	108	100	84
1804	92	17	109	137	97	27	85	82	80	82	123	119	*72*
1805	96	32	100	130	97	71	82	82	76	96	*122*	116	93
1806	103	28	99	141	78	58	90	95	86	93	127	123	102
1807	96	−9	99	136	98	83	112	101	110	110	122	113	106
1808	108	19	107	135	119	97	107	116	100	114	127	124	112
1809	111	27	78	133	91	56	76	87	56	83	129	117	88
1810	101	24	97	142	−5	62	91	97	40	97	119	117	98
...	...	...	...	...	...	...	...	...	...	...	...	...	...
1835	...	− 9	...	...	...	...	...	...	...	...	...	...	...
1836	90	6	101	*117*	113	53	81	80	...	...	115	109	81
1837	95	− 4	115	*122*	111	...	...	78	...	...	*119*	122	104
1838	93	− 5	102	*121*	...	74	...	101	...	102	*118*	102	*95*
1839	96	−17	106	*123*	119	39	...	107	...	109	123	115	*97*
1840	91	− 8	77	120	...	40	...	*90*	...	..	114	110	95
...	...	...	...	...	...	...	...	...	...	...	...	...	...
1845	...	− 3	...	..	− 6	...	...	...	...	...	...	[110]	...
1846	80	−11	69	[128]	...	35	70	61	...	81	96	106	73
1847	100	[1]	96	[132]	...	[75]	98	102	...	97	[129]	108	*102*
1848	88	9	83	134	86	61	93	93	...	93	94	[100]	91
1849	91	4	71	137	58	35	62	75	...	90	122	117	62
1850	100	25	72	[145]	[102]	58	[103]	[97]	...	[92]	[115]	[111]	[99]
1851	93	[1]	[73]	[138]	[49]	[35]	[109]	[90]	...	88	114	107	88
1852	99	18	[77]	134	[84]	[37]	[107]	[92]	...	80	[117]	[114]	96
1853	103	− 9	[92]	150	95	[80]	109	[106]	...	109	[132]	109	100
1854	87	16	[71]	[105]	92	[61]	88	98	...	110	106	103	89
1855	102	− 6	103	134	123	103	115	108	96	108	136	114	107
1856	103	25	79	142	107	66	114	101	111	99	133	116	101
1857	95	3	76	135	102	57	97	97	100	96	123	105	94

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OLOGICAL OBSERVATIONS—*continued*.

			BIRDS.										
			MIGRATION.				OTHERS.						
Ash.	Lime.	Maple.	Swallow.	Cuckoo.	Nightingale.	Churn Owl Calls.	Thrush Sings.	"Ringdoves" Coo.	Rooks Build.	Young Rooks.	Yellow Butterfly Appears.	Frogs and Toads Croak.	YEAR.
109	96	105	101	106	114	119	37	40	60	90	68	75	1781
136	125	117	112	112	128	147	52	58	58	100	97	72	1782
110	92	108	110	118	102	135	31	45	68	102	77	69	1783
133	125	118	110	117	119	137	64	67	62	100	108	109	1784
122	112	114	102	117	113	138	24	77	73	106	78	98	1785
122	110	111	111	120	112	155	46	71	34	103	71	78	1786
119	88	116	108	122	117	155	35	68	66	105	49	80	1787
111	102	103	102	112	118	144	43	71	57	105	88	84	1788
118	111	114	110	113	122	166	50	43	58	104	31	90	1789
117	87	84	113	119	...	152	44	53	60	101	14	60	1790
105	95	90	98	114	127	165	45	64	61	98	84	71	1791
101	91	98	104	113	140	178	...	62	66	103	43	78	1792
120	113	111	113	120	128	170	46	53	63	102	55	74	1793
98	78	74	109	114	121	173	36	59	59	94	67	68	1794
115	110	112	109	121	111	...	64	79	64	101	81	100	1795
111	104	103	112	116	114	...	10	48	64	107	30	76	1796
118	100	105	116	120	115	...	49	50	50	98	53	74	1797
106	97	96	103	116	108	...	17	37	49	93	62	63	1798
132	126	125	109	127	127	...	50	59	55	92	55	54	1799
106	104	103	112	113	114	...	30	33	33	87	31	82	1800
109	97	96	110	119	129	...	23	42	48	94	61	61	1801
104	93	102	110	109	120	...	27	55	60	101	84	77	1802
99	95	94	106	114	113	...	50	74	65	103	81	80	1803
119	92	102	114	118	119	...	18	68	48	103	70	73	1804
119	99	99	105	118	123	...	46	46	62	98	58	74	1805
118	107	93	116	119	125	...	21	35	65	101	56	85	1806
116	104	116	117	117	118	...	−13	44	69	108	46	90	1807
126	121	121	106	124	125	...	32	52	71	101	100	101	1808
120	87	92	116	118	125	...	35	55	67	99	31	80	1809
118	109	96	109	113	114	...	3	72	66	101	106	107	1810
...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	1835
...	120	109	112	116	...	...	−12	...	60	109	79	79	1836
...	*121*	...	117	110	...	...	35	...	68	106	110	...	1837
...	*120*	...	...	108	...	...	−30	86	62	85	...	...	1838
...	123	123	106	117	106	...	−10	...	58	106	112	85	1839
...	114	114	111	116	...	...	...	...	45	105	105	73	1840
...	...	...	...	...	...	...	...	...	...	...	...	...	..
...	...	...	...	[114]	...	...	...	...	...	...	...	80	1845
...	105	...	93	111	110	...	−24	52	47	82	[100]	54	1846
...	120	...	[118]	113	[127]	[128]	46	95	55	101	74	90	1847
113	94	113	[109]	[108]	119	...	−21	3	51	94	82	89	1848
122	120	...	117	[117]	[118]	139	20	61	[70]	91	48	96	1849
[129]	[107]	[110]	[107]	109	[128]	[160]	42	56	[60]	[105]	[73]	[63]	1850
[130]	[115]	[108]	108	[112]	120	...	...	[5]	59	[96]	[109]	[90]	1851
[137]	120	...	114	114	[129]	[154]	...	...	[67]	[102]	71	66	1852
[133]	[131]	...	[113]	[121]	108	[190]	−16	99	65	[114]	72	[95]	1853
108	95	[104]	102	123	124	...	32	57	[65]	103	62	85	1854
133	118	...	115	125	...	[166]	7	64	64	112	96	89	1855
134	106	...	116	116	122	...	25	101	58	100	47	64	1856
138	108	...	108	125	110	135	−42	105	67	103	48	78	1857

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TABLE I.—THE MARSHAM

YEAR.	PLANTS.														
		FLOWERING.				LEAFING.									
	Mean of 7 Plants.	Snowdrop.	Wood Anemone.	Hawthorn.	Turnip.	Hawthorn.	Sycamore.	Birch.	Elm (Common).	Mountain Ash.	Oak.	Beech.	Horse-Chestnut.	Chestnut.
1781	91	29	85	118	97	68	81	83	85	83	109	105	100	110
1782	102	4	102	139	100	51	93	100	100	...	134	115	100	131
1783	92	26	91	117	82	54	97	91	92	91	114	109	96	109
1784	111	39	113	135	135	113	114	114	127	113	130	122	114	130
1785	102	24	106	122	117	102	109	108	109	108	125	113	109	119
1786	104	22	101	135	115	85	108	106	109	106	126	118	108	126
1787	90	30	75	121	81	56	81	77	77	76	116	115	80	114
1788	93	12	90	127	104	62	95	94	101	95	115	109	95	111
1789	103	25	105	129	130	89	106	107	111	106	127	115	109	124
1790	88	19	75	120	18	49	79	73	71	80	122	117	79	95
1791	87	16	77	128	56	64	80	82	77	81	105	105	81	95
1792	87	25	92	117	98	75	82	85	88	81	104	103	81	102
1793	95	15	93	131	93	61	84	84	95	95	125	117	82	122
1794	77	16	75	111	55	53	68	71	67	72	99	99	66	87
1795	101	41	100	131	131	98	105	106	112	106	119	112	91	122
1796	91	20	85	113	10	50	89	91	83	95	110	110	89	101
1797	94	22	90	138	97	69	93	90	96	90	117	110	83	117
1798	89	16	94	122	59	53	73	96	67	93	107	105	79	105
1799	112	23	110	153	...	90	105	111	78	111	140	122	111	111
1800	98	26	98	136	110	88	102	101	100	100	112	107	97	108
1801	89	13	92	123	90	63	89	88	88	91	115	108	78	105
1802	91	36	95	118	100	78	87	92	84	88	112	107	82	101
1803	90	48	97	110	100	85	87	88	84	92	108	100	84	101
1804	92	17	109	137	97	27	85	82	80	82	123	119	72	108
1805	96	32	100	130	97	71	82	82	76	96	122	116	93	112
1806	103	28	99	141	78	58	90	95	86	93	127	123	102	107
1807	96	−9	99	136	98	83	112	101	110	110	122	113	106	113
1808	108	19	107	135	119	97	107	116	100	114	127	124	112	120
1809	111	27	78	133	91	56	76	87	56	83	129	117	88	117
1810	101	24	97	142	−5	62	91	97	40	97	119	117	98	114
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1835	...	− 9	...	...	...	...	...	...	...	...	...	...	...	...
1836	90	6	101	*117*	113	53	81	80	...	...	115	109	81	...
1837	95	− 4	115	*122*	111	...	...	78	...	...	*119*	122	104	...
1838	93	− 5	102	*121*	...	74	...	101	...	102	*118*	102	95	...
1839	96	−17	106	*123*	119	39	...	107	...	109	123	115	*97*	...
1840	91	− 8	77	120	...	40	...	*90*	...	..	114	110	95	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1845	...	− 3	...	..	− 6	...	...	...	...	...	...	[110]	...	...
1846	80	−11	69	[128]	...	35	70	61	...	81	96	106	73	105
1847	100	[1]	96	[132]	...	[75]	98	102	...	97	[129]	108	102	128
1848	88	9	83	134	86	61	93	93	...	93	94	[100]	91	101
1849	91	4	71	137	58	35	62	75	...	90	122	117	62	122
1850	100	25	72	[145]	[102]	58	[103]	[97]	...	[92]	[115]	[111]	[99]	[115]
1851	93	[4]	[73]	[138]	[49]	[35]	[100]	[90]	...	88	[114]	107	88	111
1852	99	18	[77]	134	[84]	[37]	[107]	[92]	...	80	[117]	[114]	96	[122]
1853	103	− 9	[92]	150	95	[80]	100	[106]	...	109	[132]	109	100	130
1854	87	16	[71]	[105]	92	[61]	88	98	...	110	106	103	89	102
1855	102	− 6	103	134	123	103	115	108	96	108	136	114	107	138
1856	103	25	79	142	107	66	114	101	111	99	133	116	101	115
1857	95	3	76	135	102	57	97	97	100	96	123	105	94	110

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PHENOLOGICAL OBSERVATIONS—*continued.*

				BIRDS.										
				MIGRATION.				OTHERS.						
Hornbeam.	Ash.	Lime.	Maple.	Swallow.	Cuckoo.	Nightingale.	Churn Owl Calls.	Thrush Sings.	"Ringdoves" Coo.	Rooks Build.	Young Rooks.	Yellow Butterfly Appears.	Frogs and Toads Croak.	YEAR.
93	109	96	105	101	106	114	119	37	40	60	90	68	75	1781
112	136	125	117	112	112	128	147	52	58	58	100	97	72	1782
104	110	92	108	110	118	102	135	31	45	68	102	77	69	1783
118	133	125	118	110	117	119	137	64	67	62	100	108	109	1784
109	122	112	114	102	117	113	138	24	77	73	106	78	98	1785
108	122	110	111	111	120	112	155	46	71	34	103	71	78	1786
77	119	88	116	108	122	117	155	35	68	66	105	49	80	1787
95	111	102	103	102	112	118	144	43	71	57	105	88	84	1788
94	118	111	114	110	113	122	166	50	43	58	104	31	90	1789
70	117	87	84	113	119	...	152	44	53	60	101	14	60	1790
75	105	95	90	98	114	127	165	45	64	61	98	84	71	1791
88	101	91	98	104	113	140	178	...	62	66	103	43	78	1792
79	120	113	111	113	120	128	170	46	53	63	102	55	74	1793
96	98	78	74	109	114	121	173	36	59	59	94	67	68	1794
106	115	110	112	109	121	111	...	64	79	64	101	81	100	1795
90	111	104	103	112	116	114	...	10	48	64	107	30	76	1796
84	118	100	105	116	120	115	...	49	50	50	98	53	74	1797
75	106	97	96	103	116	108	...	17	37	49	93	62	63	1798
114	132	126	125	109	127	127	...	50	59	55	92	55	54	1799
90	106	104	103	112	113	114	...	30	33	33	87	31	82	1800
67	109	97	96	110	119	129	...	23	42	48	94	61	61	1801
86	104	93	102	110	109	120	...	27	55	60	101	84	77	1802
76	99	95	94	106	114	113	...	50	74	65	103	81	80	1803
82	119	92	102	114	118	119	...	18	68	48	103	70	73	1804
77	119	99	99	105	118	123	...	46	46	62	98	58	74	1805
88	118	107	93	116	119	125	...	21	35	65	101	56	85	1806
100	116	104	116	117	117	118	...	−13	44	69	108	46	90	1807
100	126	121	121	106	124	125	...	32	52	71	101	100	101	1808
82	120	87	92	116	118	125	...	35	55	67	99	31	80	1809
91	118	109	96	109	113	114	...	3	72	66	101	106	107	1810
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	1835
73	...	120	109	112	116	...	...	−12	...	60	109	79	79	1836
71	...	*121*	...	117	110	...	...	35	...	68	106	110	...	1837
95	...	*120*	...	...	108	...	...	−30	86	62	85	...	...	1838
...	...	123	123	106	117	106	...	−10	...	58	106	112	85	1839
...	...	114	114	111	116	...	...	...	...	45	105	105	73	1840
...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
...	...	...	...	...	[114]	...	...	...	...	...	...	...	80	1845
71	...	105	...	93	111	110	...	−24	52	47	82	[100]	54	1846
96	...	129	...	[118]	113	[127]	[128]	46	95	55	101	74	90	1847
86	113	94	113	[109]	[108]	119	...	−21	3	51	94	82	89	1848
82	122	120	...	117	[117]	[118]	139	20	61	[70]	91	48	96	1849
[89]	[129]	[107]	[110]	[107]	109	[128]	[160]	42	56	[60]	[105]	[73]	[63]	1850
[71]	[130]	[115]	[108]	108	[112]	120	...	...	[5]	59	[96]	[109]	[90]	1851
30	[137]	[120]	...	114	114	[129]	[154]	...	...	[67]	[102]	71	66	1852
93	[133]	[131]	...	[113]	[121]	108	[190]	−16	99	65	[114]	72	[95]	1853
[91]	108	95	[104]	102	123	124	...	32	57	[65]	103	62	85	1854
106	133	118	...	115	125	...	[166]	7	64	64	112	96	89	1855
93	134	106	...	116	116	122	...	25	101	58	100	47	64	1856
91	138	108	...	108	125	110	135	−42	105	67	103	48	78	1857

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TABLE I.—

Year.	PLANTS.												
	Mean of 7 plants.	Flowering.				Leafing.							
		Snowdrop.	Wood Anemone.	Hawthorn.	Turnip.	Hawthorn.	Sycamore.	Birch.	Elm (Common).	Mountain Ash.	Oak.	Beech.	
1858	100	11	84	144	...	80	[121]	114	[111]	115	115	114	
1859	80	− 8	...	131	...	61	[96]	88	[93]	93	94	97	
1860	101	10	...	147	...	97	[104]	102	...	108	125	109	
1861	96	32	77	146	100	58	...	85	...	84	116	115	
1862	94	3	74	129	93	46	102	*96*	110	93	112	112	
1863	90	15	67	125	15	52	96	91	100	93	100	111	
1864	98	10	87	132	...	84	99	109	111	99	110	*113*	
1865	97	4	100	139	122	92	103	101	107	103	114	110	
1866	95	11	87	131	105	70	101	*96*	101	101	113	106	
1867	*96*	25	...	...	...	...	...	...	...	...	...	...	
1868	*93*	...	...	...	...	69	...	...	...	...	...	...	
1869	89	2	91	122	94	45	...	94	...	94	106	104	
1870	101	35	94	*135*	...	78	104	103	...	105	116	112	
1871	85	−16	86	129	...	65	80	89	...	82	108	111	
1872	85	14	72	127	...	47	101	73	92	89	107	106	
1873	93	− 5	88	*133*	...	39	108	100	...	100	109	112	
1874	90	17	79	120	...	40	83	98	94	99	98	110	
1875	97	15	86	133	...	63	98	107	...	107	117	102	
1876	94	19	90	139	...	68	84	98	112	94	109	109	
1877	95	7	66	140	...	44	104	99	...	113	121	102	
1878	90	15	67	128	...	55	82	105	...	102	111	74	
1879	101	34	90	134	...	80	102	80	[111]	101	135	116	
1880	90	34	67	109	...	58	...	78	98	80	110	110	
1881	97	7	88	128	...	85	100	103	110	103	116	118	
1882	77	−16	63	122	...	54	82	77	84	84	89	96	
1883	94	− 5	56	*133*	...	63	56	97	...	97	115	116	
1884	88	16	62	132	...	48	76	82	83	83	100	110	
1885	95	6	76	122	...	50	106	103	100	108	110	109	
1886	94	6	85	136	...	84	103	94	101	101	113	117	
1887	102	7	88	139	...	80	100	109	89	113	121	120	
1888	104	1	102	138	...	66	104	108	112	119	128	121	
1889	95	−1	98	135	...	78	97	78	91	107	117	119	
1890	90	6	74	131	...	47	80	90	96	93	109	113	
1891	103	14	87	132	...	64	94	111	113	111	121	121	
1892	103	20	85	*134*	...	93	...	111	120	...	115	123	
1893	80	21	73	112	94	77	80	64	95	92	94	92	
1894	83	−11	77	116	107	61	92	96	102	96	100	94	
1895	100	50	87	119	113	102	79	104	121	106	113	112	
1896	89	26	82	108	93	77	87	87	106	95	109	101	
1897	91	18	81	128	100	60	76	80	...	80	102	105	
1898	93	9	69	145	103	73	100	89	124	102	106	108	
1899	99	10	70	*130*	119	90	113	110	100	98	112	123	
1900	101	4	74	149	119	98	108	114	116	106	114	109	
1901	100	1	82	151	113	108	65	100	109	111	115	111	
1902	98	12	87	148	110	79	106	92	108	94	117	114	
1903	86	29	80	136	90	38	93	86	86	75	95	93	
1904	99	31	87	136	111	91	106	96	105	102	111	111	
1905	96	27	75	142	111	50	84	89	88	92	118	104	
1906	93	10	77	142	96	75	81	81	78	99	112	111	
1907	95	36	85	128	123	76	92	88	98	93	114	109	
1908	105	30	86	142	122	64	81	102	95	103	127	122	

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PHENOLOGICAL OBSERVATIONS—*continued.*

				BIRDS.										
				MIGRATION.				OTHERS.						
Hornbeam.	Ash.	Lime.	Maple.	Swallow.	Cuckoo.	Nightingale.	Churn Owl Calls.	Thrush Sings.	"Ringdoves" Coo.	Rooks Build.	Young Rooks.	Yellow Butterfly Appears.	Frogs and Toads Croak.	YEAR.
106	126	114	...	108	109	[108]	...	35	−7	69	110	75	80	1858
87	97	86	...	117	110	...	...	49	...	60	99	[60]	85	1859
[90]	...	122	...	108	120	...	...	...	...	63	114	[88]	92	1860
109	139	90	...	114	121	...	...	...	84	56	105	...	85	1861
112	123	106	...	111	105	106	...	12	77	66	104	119	71	1862
92	116	103	...	113	103	117	...	...	31	52	103	62	64	1863
105	111	110	...	103	114	121	...	...	101	62	105	84	100	1864
108	113	108	...	108	106	107	...	−24	− 1	60	107	89	97	1865
...	111	109	...	106	109	109	...	−42	...	67	87	88	88	1866
...	...	...	...	*106*	108	...	...	49	...	...	...	38	...	1867
89	...	...	...	*110*	112	...	...	...	...	59	...	...	...	1868
109	111	106	...	102	112	112	117	1	16	70	...	101	97	1869
117	...	104	...	109	109	109	...	34	78	57	99	95	99	1870
89	125	90	...	106	108	117	...	36	38	54	93	63	84	1871
...	113	89	...	119	105	114	126	− 3	...	56	87	66	92	1872
100	...	108	...	*112*	121	106	151	...	...	50	101	85	85	1873
97	121	98	...	112	113	117	145	...	...	59	85	82	80	1874
...	130	110	...	105	110	114	133	28	94	66	100	96	86	1875
113	114	94	...	111	111	113	150	...	...	44	96	88	81	1876
111	...	100	...	105	117	104	[143]	...	...	63	102	93	113	1877
74	120	102	...	107	119	101	...	...	83	51	103	96	...	1878
119	136	105	...	114	114	113	...	40	39	46	93	65	[113]	1879
110	98	94	...	109	110	109	...	39	85	41	97	108	69	1880
120	...	104	...	123	120	104	...	...	...	56	103	73	70	1881
86	125	90	...	110	118	105	...	1	...	58	97	69	60	1882
...	129	107	...	116	105	...	...	− 1	...	52	107	123	96	1883
93	116	89	...	112	103	97	...	...	...	51	104	76	67	1884
100	117	107	...	106	113	92	...	29	...	55	99	74	59	1885
114	117	98	...	113	113	95	...	−26	...	66	107	101	80	1886
125	127	112	...	115	114	101	...	...	...	48	104	58	114	1887
124	...	118	...	109	118	...	...	...	...	59	104	70	76	1888
125	135	109	...	115	118	...	...	...	...	56	98	114	78	1889
86	131	93	...	114	114	119	...	...	...	67	109	93	69	1890
124	136	117	...	106	118	...	...	...	...	59	88	59	75	1891
...	...	111	...	103	117	...	...	80	...	68	91	93	...	1892
91	100	94	71	105	107	111	134	29	33	61	95	59	58	1893
92	103	94	114	106	105	117	...	23	60	51	98	119	53	1894
110	126	100	115	96	108	118	...	21	77	66	102	98	77	1895
95	133	100	101	111	112	121	...	23	65	66	109	82	77	1896
85	121	92	106	110	113	111	...	10	32	53	97	84	76	1897
92	122	100	124	122	113	130	136	12	25	59	108	98	85	1898
96	127	114	98	120	114	...	133	8	15	58	97	41	92	1899
110	118	114	107	108	113	117	123	33	95	56	101	109	91	1900
112	117	112	117	109	103	104	124	23	24	61	105	71	96	1901
94	112	112	112	104	111	112	130	44	115	59	103	89	69	1902
86	117	83	102	123	118	138	...	33	80	44	95	93	77	1903
105	109	105	102	133	118	...	140	40	74	67	102	102	83	1904
103	105	92	92	114	114	...	...	37	34	56	95	95	151	1905
100	121	99	93	108	119	...	...	28	100	63	99	96	...	1906
100	125	100	100	113	120	...	...	46	37	66	103	80	91	1907
123	128	117	118	121	118	...	...	37	73	61	104	119	127	1908

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TABLE I.—THE

Year.	Plants. Mean of 7 plants.	Flowering. Snowdrop.	Flowering. Wood Anemone.	Flowering. Hawthorn.	Flowering. Turnip.	Leafing. Hawthorn.	Leafing. Sycamore.	Leafing. Birch.	Leafing. Elm (Common).	Leafing. Mountain Ash.	Leafing. Oak.	Leafing. Beech
1909	101	24	96	143	127	101	104	109	98	105	116	1
1910	100	33	82	138	111	64	103	108	95	87	109	1
1911	99	12	76	139	118	61	87	104	91	104	113	1
1912	82	10	82	117	110	62	75	84	86	85	98	
1913	86	6	44	124	97	42	82	80	110	72	101	1
1914	87	6	74	121	109	61	84	93	89	93	94	1
1915	100	27	75	134	136	83	84	107	122	102	118	1
1916	99	16	91	131	106	36	94	111	102	97	117	1
1917	114	44	109	135	132	116	117	124	118	120	128	1
1918	93	24	70	133	98	54	86	83	92	92	116	1
1919	99	8	95	129	107	55	99	107	101	102	121	1
1920	84	8	70	119	95	50	72	95	80	69	95	1
1921	77	6	75	115	84	53	77	73	86	81	93	
1922	103	29	71	141	...	66	103	96	118	116	123	1
1923	93	20	70	126	84	68	68	102	102	87	94	1
1924	104	22	97	145	126	76	100	109	112	109	123	1
1925	96	6	60	138	96	46	87	106	95	103	110	1
Averages												
1731—1740	...	...	...	(160)	(99)	(86)	(91)	...	...	...	...	...
1741—1750	104	21	...	138	100	81	96	96	...	...	(120	(1
1751—1760	98	20	...	135	96	73	95	91	89	95	118	1
1761—1770	96	16	(86)	132	85	64	99	92	84	102	117	1
1771—1780	95	17	88	128	96	75	93	88	91	91	116	1
1781—1790	98	23	94	126	98	73	96	95	98	95	122	1
1791—1800	93	22	91	128	79	70	88	92	86	92	114	1
1801—1810	96	24	97	131	87	68	91	93	80	95	120	1
1831—1840	93	—6	100	(120)	(114)	(51)	(81)	(92)	...	(106)	(117)	1
1841—1850	92	4	78	135	(60)	53	85	86	...	91	111	1
1851—1860	98	8	82	136	93	68	106	100	102	101	119	1
1861—1870	95	15	85	132	88	66	101	97	106	97	111	1
1871—1880	92	13	79	129	...	56	94	93	101	97	113	1
1881—1890	94	3	79	131	...	66	90	94	96	101	112	1
1891—1900	95	16	79	126	106	80	92	97	111	98	109	1
1901—1910	97	23	84	141	111	75	97	95	96	96	113	1
1911—1920	94	17	79	128	111	62	88	99	99	94	110	1
1921—1930	95	17	75	133	(98)	62	87	97	103	99	109	1
1751—1785	97	19	91	131	96	72	96	92	90	96	118	1
1891—1925	96	19	79	132	108	71	90	97	102	96	110	1
Average of all Records	95 Apr. 5	16 Jan. 16	85 Mar. 26	132 May 12	96 Apr. 6	68 Mar. 9	93 Apr. 3	94 Apr. 4	95 Apr. 5	96 Apr. 6	115 Apr. 25	11 Ap 23
No. of Observns.	...	146	121	144	118	152	142	142	115	132	145	14
Earliest ...	Mar. 15 1779	Dec. 15 1838	Feb. 13 1913	Apr. 15 1854	Dec. 26 1844	Jan. 27 1804	Feb. 25 1883	Mar. 2 1846	Feb. 9 1810	Mar. 5 1779	Mar. 30 1882	Ma 15 187
Latest ...	Apr. 26 1771	Feb. 19 1895	Apr. 25 1837	June 8 1740	May 16 1915	Apr. 26 1917	May 4 1771	May 4 1771/ 1917	May 4 1898	May 2 1766/ 1771	May 20 1799	Ma 12 174

Decade averages based on less than five observations are shown in brackets; the actual number of observations can of course be seen in the table.

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PHENOLOGICAL OBSERVATIONS—*continued.*

					BIRDS.									
					MIGRATION.				OTHERS.					
Chestnut.	Hornbeam.	Ash.	Lime.	Maple.	Swallow.	Cuckoo.	Nightingale.	Churn Owl Calls.	Thrush Sings.	"Ringdoves" Coo.	Rooks Build.	Young Rooks.	Yellow Butterfly Appears.	Frogs and Toads Croak.
106	101	132	108	109	100	111	...	...	34	86	73	108	100	80
106	93	111	100	123	119	117	...	...	38	7	57	97	86	71
107	100	120	104	112	108	115	...	...	28	68	65	118	109	96
95	76	115	85	98	124	114	...	...	41	14	66	98	94	...
112	74	110	96	93	109	112	...	...	38	71	61	103	93	112
102	83	100	96	96	102	108	...	...	46	50	69	100	103	83
116	96	108	104	118	117	119	117		36	134	74	110	74	120
114	112	116	101	117	114	112	...	...	16	119	67	115	79	77
124	124	132	122	126	120	119	...	...	3	122	60	120	116	...
106	102	122	86	92	130	120	...	...	21	133	67	112	71	71
122	107	125	110	108	125	114	...	...	18	129	56	122	94	92
107	90	117	85	89	106	109	...	...	18	128	86	115	113	81
84	98	98	77	104	119	116	...	...	2	120	50	102	94	70
127	116	128	110	126	127	119	...	...	14	133	65	114	96	142
105	102	103	115	...	106	102	...	...	17	122	57	110	86	81
117	112	133	111	123	115	115	...	...	24	123	69	112	98	110
106	111	123	104	113	111	113	...	...	37	129	56	109	97	98
...	...	...	...	...	(105)	(118)	(130)	(153)	(26)	...	(69)	...	...	...
...	...	...	(132)	...	108	119	117	147	35	37	63	102	(51)	83
(100)	(93)	119	(112)	(107)	102	115	109	143	35	45	66	103	(74)	82
113	109	123	103	(115)	104	117	119	152	29	(63)	64	106	(69)	84
116	102	123	102	109	106	115	126	139	44	55	62	98	65	79
117	99	120	105	109	108	116	116	145	43	59	60	102	68	82
107	87	111	102	102	109	117	121	(172)	38	54	56	98	56	74
110	88	115	100	101	111	117	121	...	24	54	62	101	69	84
...	(82)	...	(119)	(115)	(112)	113	(106)	...	(−4)	(86)	59	102	(102)	(79)
114	81	(121)	111	(111)	109	112	120	(109)	13	53	57	95	75	79
116	88	126	112	(106)	111	118	117	(161)	13	61	64	105	73	82
105	103	118	105	...	108	110	111	(117)	5	55	61	101	85	88
102	103	120	99	...	110	113	111	141	28	68	53	96	84	89
101	108	125	103	...	113	114	102	...	(1)	...	57	103	85	77
111	100	121	104	105	109	112	118	(132)	27	50	60	99	84	76
107	102	118	103	107	114	114	(118)	(131)	36	63	61	101	93	94
111	96	117	99	105	116	114	(117)	...	27	128	67	111	95	92
108	108	117	103	(117)	116	113	...	...	19	125	59	109	94	100
115	103	122	105	110	105	115	117	142	37	54	64	102	71	82
109	101	118	102	107	113	113	118	(133)	28	56	62	104	91	80
110	97	119	104	107	109	115	116	144	27	53	61	102	79	83
Apr.	Apr.	Apr.	Apr.	Apr.	Apr.	Apr.	Apr.	May	Jan.	Feb.	Mar.	Apr.	Mar.	Mar.
20	7	29	14	17	19	25	26	24	27	22	2	12	20	24
122	127	125	134	85	153	158	118	68	131	104	147	144	128	143
Mar.	Feb.	Apr.	Mar.	Mar.	Apr.	Apr.	Apr.	Apr.	Nov.	Dec.	Feb.	Mar.	Jan.	Feb.
15	8	2	18	12	3	12	2	27	20	25	2	23	14	22
1882	1852	1779	1921	1893	1846	1923	1885	1869	1856/1865	1857	1800	1846	1790	1894
May	May	May	May	May	May	May	May	July	Mar.	Apr.	Mar.	May	May	May
18	7	26	12	7	12	7	23	9	20	25	26	2	3	31
1855	1771	1772	1746	1770/1771	1904	1767/1799	1769	1853	1892	1902	1920	1919	1883	1905

The *true* Turtledove records for 1915-25 have been *excluded* from the averages, etc., in the above summary of the column "Ringdoves coo," their mean for the eleven years being 127 (May 7).

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The annual means of these (referred to in all that follows as the Marsham seven plants) were obtained, and compared with those of the plants on the Society's schedule, hazel to hawthorn (by chance also seven), which come within the same period, January to May, for the 34 years 1891 to 1924, both for England East and for the British Isles.

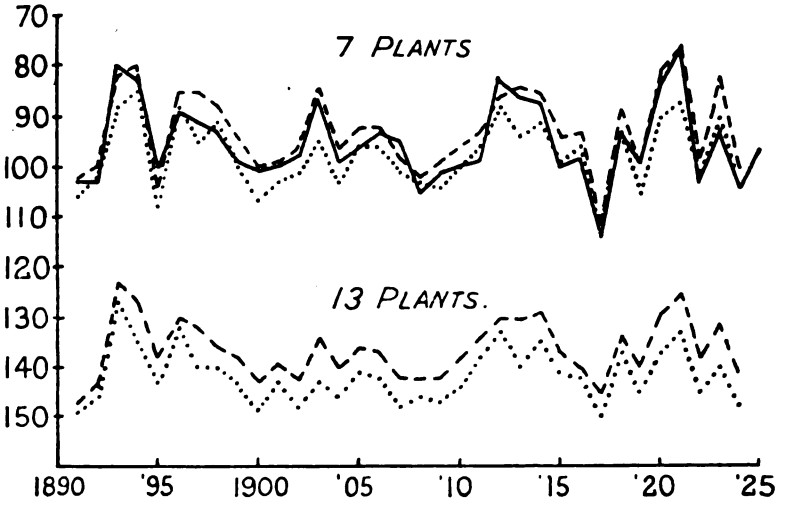

FIG. 1.—Comparison of the annual means of the Marsham seven plants with the Society's seven and thirteen plants.

The vertical scale shows dates by day of year.

Marsham plants ———. Society's plants (England East) — — — —

Society's plants (British Isles) .....

The result is shown graphically in Fig. 1, and it is clear that the agreement with the Society's England East figures is wonderfully close, for it must be remembered that the Marsham values are based on a single station, liable to many chance effects, while the Society's values are district means in which these are mainly eliminated. It says much for the care with which the Marsham records were kept. Even the values for the British Isles are seen to be closely related.

For these years the average date (days from January 1st) of the Marsham seven plants is 95 (April 5), of the Society's seven plants in England East 92 (April 2), and for the British Isles 98 (April 8). If the yearly means of the Marsham seven plants, corrected respectively by −3 or +3 for the difference of the averages, be compared with the corresponding yearly values of the means of the Society's seven plants hazel to hawthorn for England East, or for the British Isles, the agreement, especially for England East, will be found very satisfactory. Table II. shows the frequency of the variations from complete agreement, and it should be noted that for England East only five years of the 34 show a divergence of five days or more, the greatest being −7 days (1895 and 1912) and +8 days (1923).

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TABLE II.—Accuracy of Agreement of the Marsham Observations with those of the Society.

Frequency of deviations from complete agreement of the annual means of the Marsham Plants and Cuckoo (allowance being made, as shown, for the average difference) with the Society's series.

Deviations from complete agreement (days).	Marsham 7 plants (less 3 days) and Society's 7 plants in Eng. East.	Marsham 7 plants (plus 41 days) and Society's 13 plants in Eng. East.	Marsham 7 plants (plus 2 days) and Society's 7 plants in British Isles.	Marsham 7 plants (plus 46 days) and Society's 13 plants in British Isles.	Marsham 6 plants (plus 2 days) and Society's 6 plants in Eng. East.	Marsham cuckoo (less 2 days) and Society's cuckoo in Eng. East.
+ 5 etc.	1	4	6	4	1	4
+ 4	—	2	4	1	2	1
+ 3	4	5	4	5	3	6
+ 2	4	3	1	4	3	5
+ 1	4	2	1	1	3	2
0	5	7	5	3	6	6
− 1	6	1	3	4	6	5
− 2	5	1	—	2	3	1
− 3	1	3	5	2	2	1
− 4	—	3	—	1	1	—
− 5 etc.	4	3	5	7	4	3

A similar comparison with the yearly means of the Society's 13 plants for England East and British Isles is also given, and the agreement, though not quite so close, is still distinctly significant, although the 13 plants cover a period about two months longer.

Correlation coefficients were also obtained for these comparisons, and are given in Table III. They range from +.81 to +.93.

TABLE III.—Correlation Coefficients.

Correlation. A.	B.	Standard Deviation of A.	Standard Deviation of B.	Correlation Coefficient.
Marsham 7 plants	Society's 7 (Eng. E.)	8.21	8.20	+.93
,, ,, ,,	,, 13 (Eng. E.)	8.21	5.90	+.89
,, ,, ,,	,, 7 (British Isles)	8.21	6.93	+.88
,, ,, ,,	,, 13 (British Isles)	8.21	5.62	+.81
,, ,, ,,	Temp. (Jan.-May)*	8.21	1.43	−.82
,, ,, ,,	Temp. (Jan.-May)†	7.65	1.98	−.61
,, ,, ,,	Sunspot Numbers‡	6.65	29.84	−.49
,,	Cuckoo and Society's (Eng. E.)	4.98	3.52	+.62

* Period 1891-1924.
† 1771-1810, 1836-40 and 1846-1925 (all available years).
‡ Period 1871-1905.
All other periods are 1891-1924.

The relation of the Marsham six plants (omitting snowdrop) with the corresponding five in the Society's list (hazel and coltsfoot omitted) was also investigated. This covers a much shorter period, March to May, and it was thought that any tendency of snowdrop (the isolated early event of the seven) to be erratic would thus be eliminated. The comparisons shown were equally satisfactory (that for England East is included in Table II.), but as no definite advan-

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tage was gained, it seemed preferable to include the snowdrop and so make the Marsham plant mean comparable with the whole of the Society's list down to hawthorn, representing the months January to May.

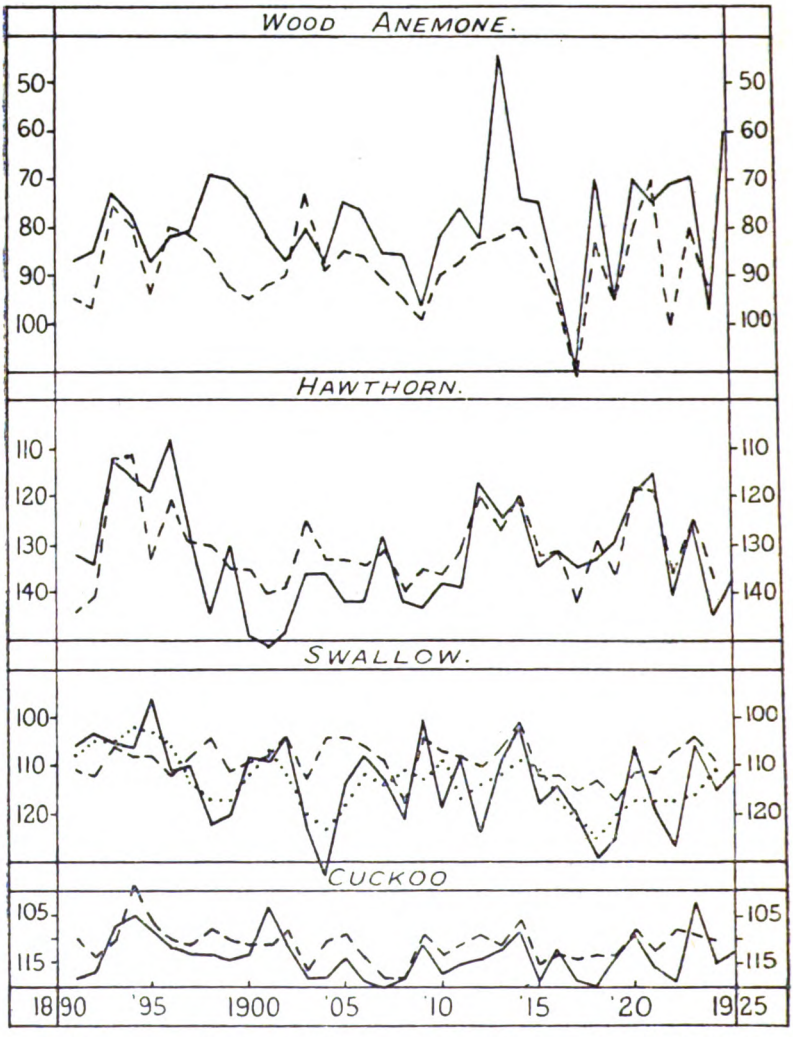

FIG. 2.—Comparison of individual Marsham plant and bird records with the Society's means for England East.

The vertical scale shows dates by day of year.

Marsham series ———. Society's series — — —

(Marsham swallow, smoothed, ...)

To illustrate the relation of *single* plant records in the Marsham and Society's series, the annual values of wood anemone and hawthorn flowering are shown in Fig. 2. The averages for the 34 years (35 years for the Marsham plants) are in very good agreement

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for hawthorn, but it is clear that considerable yearly divergences occur. Wood anemone is much less satisfactory, the Marsham average being nine days earlier than the Society's, while the yearly differences are often considerable. In the case of hawthorn the agreement is quite good, indeed remarkably close for the records of a single station, and this is particularly welcome since the hawthorn event is very useful in phenological work, and the Marsham series is complete from 1740.

It is thus evident that the annual mean of the Marsham seven plants may be taken as a reliable index in these early years for comparison with the Society's plant means, with, for England East, an error of only about ± 3 days from the mean of the first seven plants, hazel to hawthorn.

With the birds less satisfactory results are obtained. The averages for the 34 years agree well with those of England East, and the yearly variations are of course smaller than with individual plants. The cuckoo values show the best agreement, and a correlation coefficient of $+.62$ was obtained with the Society's England East values, while even the mean dates for the British Isles are in quite good agreement. The swallow is too erratic for satisfactory annual comparison, while the nightingale series, which also appears very erratic (due possibly to the proximity of its geographical limit), does not continue long enough to give a good comparative period. The comparisons are shown graphically in Fig. 2.

III.—Examination of the Whole Recorded Period.

The remarkable length of this record affords a good opportunity for studying the relations of yearly changes over a long period, and some important points which it has brought to light will now be discussed.

It is most unfortunate that the record is broken from 1810 practically till 1846, but for many purposes this can be successfully bridged by two other good records which are set out in Tables IV. and V.

The first of these, by Henry Cox, was kept at Farningham, near Dartford, Kent, for 1808 to 1817, then at Limpsfield, Surrey, till 1861.[5] It provides two useful plant records, blackthorn and hawthorn flowering, for comparison with the Marsham series, and the arrival dates of swallow, cuckoo and nightingale. Its main feature, however, is a remarkably complete series of observations, twelve in number, on the date of the chief farming operations throughout each year. These should be of considerable value to students of agricultural meteorology.

The other record was kept at Thwaite, Suffolk, by Orlando Whistlecraft from 1819 to 1864.[6] It is similar in character to the Marsham record, and gives twelve good plant records, of which six (sycamore, horse chestnut, maple, willow and oak leafing, and hawthorn flowering) have been used for comparison. There are also records of the arrival of the cuckoo and estimated dates for the commencement and completion of harvest in Suffolk generally.

[5] Library, R. Meteor Soc.
[6] From a copy by A. W. Preston, F.R.Met.Soc.

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TABLE IV.—PHENOLOGICAL OBSERVATIONS AT FARNINGHAM, KEN

YEAR.	PLANTS.					BIRDS.					
	Mean of Blackthorn and Hawthorn.	Willow Flowers.	Blackthorn Flowers.	Hawthorn Flowers.	Crocus Flowers.	Swallow First Seen.	Cuckoo Heard.	Nightingale Heard.	Cuckoo Last Heard.	Swallow Last Seen.	Butterfly First Seen.
1808	131	...	122	141	...	100	122	104	...	269	64
1809	125	...	115	135	...	110	124	112	...	263	75
1810	130	...	120	140	...	108	112	111	...	274	59
1811	118	...	110	126	...	111	112	103	...	283	69
1812	137	...	118	156	...	112	122	107	...	279	51
1813	131	...	105	157	...	116	125	105	...	273	56
1814	132	...	112	152	...	107	110	103	...	271	92
1815	115	...	96	135	...	103	121	102	...	274	40
1816	147	...	133	162	...	114	113	110	...	258	72
1817	138	...	118	159	...	111	124	122	...	286	50
1818	129	...	115	143	...	106	115	113	...	288	88
1819	116	...	100	132	...	96	105	100	...	279	74
1820	127	...	111	143	..	103	109	109	...	275	71
1821	125	...	110	140	...	106	110	110	...	269	70
1822	115	74	100	130	...	111	104	111	...	271	62
1823	133	91	121	145	...	106	111	111	...	275	71
1824	140	90	124	157	...	105	116	115	...	271	77
1825	124	87	116	132	...	104	113	109	...	270	52
1826	116	75	102	130	...	109	112	106	...	263	56
1827	121	82	108	134	...	104	104	105	...	253	72
1828	124	76	110	139	...	104	115	107	...	249	69
1829	140	94	127	154	...	104	113	108	...	244	80
1830	121	85	108	135	...	91	105	100	...	260	64
1831	125	81	110	140	...	104	102	102	...	263	66
1832	131	95	116	146	...	101	114	109	184	257	69
1833	135	92	121	149	49	99	112	111	176	252	64
1834	130	75	121	140	22	99	114	113	167	244	68
1835	124	79	104	145	55	103	103	114	188	232	73
1836	137	81	118	157	62	110	109	113	...	254	79
1837	152	100	135	169	46	115	113	115	187	263	91
1838	147	93	137	157	71	107	123	113	192	264	73
1839	142	100	126	159	61	110	115	112	189	249	62
1840	130	86	115	146	55	106	106	112	171	266	93
1841	133	84	112	155	62	109	107	109	172	267	65
1842	133	86	114	152	57	112	110	113	182	261	65
1843	126	81	106	146	52	99	109	107	173	277	72
1844	130	87	113	147	76	106	112	110	168	275	86
1845	142	98	125	159	79	108	113	108	180	251	83
1846	122	71	100	145	35	103	106	104	155	263	120
1847	138	85	124	152	51	117	115	111	174	237	74
1848	135	80	118	153	49	100	112	112	171	245	64
1849	131	79	115	148	27	104	116	116	170	242	63
1850	142	89	122	162	50	105	117	102	170	253	49
1851	142	90	121	163	42	107	107	105	171	265	105
1852	138	85	116	160	46	109	111	117	179	249	80
1853	148	102	136	160	62	104	109	111	179	264	71
1854	137	79	126	148	56	105	122	110	180	263	72
1855	153	105	141	166	67	110	118	114	187	251	95
1856	128	86	116	141	54	115	114	110	...	264	47
1857	125	79	118	132	55	101	110	110	170	271	47
1858	131	91	113	150	50	105	106	106	172	262	75
1859	115	79	96	135	41	109	110	115	170	253	64
1860	148	99	135	162	57	108	112	103	178	276	95
1861	147	84	140	155	57	112	110	114	166	283	95
Average of all Records	132 May 12	86 Mar. 27	117 Apr. 27	148 May 28	53 Feb. 22	106 Apr. 16	112 Apr. 22	109 Apr. 19	170 June 19	263 Sept. 20	71 Mar. 12

* Sanfoin until 1818, then meadow grass.

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...ESHAM, 1817), AND LIMPSFIELD, SURREY, BY HENRY COX.

		CROPS.										
Oat Sowing Begun.	Oat Sowing Finished.	Hops Poled.	Hops Tied.	*Grass Mowing Begun.	Haying Finished.	Wheat in Ear.	Reaping Begun.	Harvest Finished.	Hop-Picking Begun.	Wheat Sowing Begun.	Wheat Sowing Finished.	YEAR
62	103	...	...	168	181	176	218	239	...	205	313	1808
70	117	...	...	175	196	182	222	245	...	258	322	1809
72	103	...	...	169	187	179	226	248	...	273	324	1810
70	74	...	...	154	172	161	205	238	...	259	314	1811
70	102	...	...	176	190	183	232	253	...	294	335	1812
70	116	...	...	173	185	173	224	252	...	271	315	1813
84	102	...	...	179	194	185	202	250	...	266	311	1814
63	77	...	...	161	175	173	221	238	...	282	308	1815
72	101	...	...	177	213	196	242	286	...	276	324	1816
62	92	...	...	172	195	175	227	253	...	281	326	1817
74	90	...	...	169	181	159	208	224	243	272	304	1818
70	92	...	...	170	205	170	212	237	251	274	323	1819
73	113	...	...	185	213	177	222	257	257	276	311	1820
81	115	...	...	191	225	190	233	262	253	263	312	1821
72	81	116	171	167	191	161	197	220	245	270	318	1822
80	93	122	186	188	227	170	228	263	260	279	304	1823
91	111	127	187	187	223	178	229	274	258	292	306	1824
83	97	118	169	179	199	171	203	233	†	288	290	1825
86	96	116	167	177	199	172	204	227	247	277	307	1826
85	100	119	180	176	202	175	215	240	257	281	305	1827
85	101	123	182	181	229	172	213	239	259	282	302	1828
85	90	127	181	196	244	175	216	279	264	285	304	1829
85	98	114	163	186	214	177	221	244	256	279	300	1830
91	106	122	171	183	208	167	210	234	241	288	307	1831
93	102	122	182	184	210	173	217	248	254	290	296	1832
88	102	127	183	180	216	169	212	233	259	282	303	1833
85	98	116	193	169	211	167	204	224	258	274	325	1834
85	95	122	175	182	206	166	208	227	247	287	292	1835
95	110	125	183	186	209	172	223	249	256	288	298	1836
88	102	126	173	186	205	183	226	247	254	282	307	1837
90	96	130	167	194	222	182	225	244	262	281	299	1838
85	102	126	171	189	215	176	219	257	259	281	312	1839
85	98	122	153	183	212	172	216	245	258	281	302	1840
85	102	114	155	184	239	177	224	253	256	293	310	1841
85	105	117	168	185	204	166	213	234	243	277	281	1842
88	88	119	187	184	233	175	223	249	261	287	292	1843
88	104	116	168	209	233	172	211	242	260	284	297	1844
91	98	132	187	188	249	187	233	263	272	287	291	1845
92	114	115	181	182	221	174	204	227	250	290	306	1846
85	90	121	177	184	207	177	214	240	253	281	293	1847
122	123	127	192	185	250	178	213	259	283	264	309	1848
90	90	111	153	160	194	179	222	251	253	282	302	1849
94	94	117	179	175	221	181	219	252	254	280	290	1850
106	106	125	184	184	214	181	223	244	260	288	300	1851
96	96	122	178	188	213	177	216	255	257	292	296	1852
103	103	124	177	187	221	187	230	260	269	305	319	1853
101	101	126	174	200	224	189	227	248	268	285	306	1854
95	95	125	188	185	227	191	225	242	253	285	297	1855
89	89	120	171	179	215	182	226	240	248	285	298	1856
105	105	118	171	169	196	166	205	228	245	283	302	1857
86	86	121	170	166	207	167	209	235	249	288	307	1858
85	85	113	190	173	199	165	207	224	248	297	318	1859
102	102	119	195	191	245	194	247	279	275	296	301	1860
100	100	113	187	182	211	167	222	230	255	277	288	1861
99	99	121	177	180	211	176	218	246	254	281	306	Average
Apr.	Apr.	May	June	June	July	June	Aug.	Sept.	Sept.	Oct.	Nov.	of all
9	9	1	26	29	30	25	6	3	11	8	2	Records

† 1825. The crop of hops (12 acres) was a failure, only realising 2 lbs. per acre.

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TABLE V.—Phenological Observations at Thwaite, Suffolk, by Orlando Whistlecraft.

Year.	*Mean of 6 Plants.	Hawthorn Leaf Began to Open.	Sycamore Leaf.	Cowslip Flower.	Horse-Chestnut Leaf.	Maple Leaf.	Willow Leaf.	Tall Poplar Leaf.	Oak Leaf.	Ash Leaf.	Wych Elm Leaf.	Cuckoo Sang.	Hawthorn Flower.	Dog Rose Flower.	†Harvest Began.	
1819	117	78	100	...	105	124	110	123	132	137	...	...	130	157	210	
1820	125	95	107	...	111	134	117	133	140	142	...	...	139	166	220	
1821	118	92	102	...	105	124	111	124	132	138	..	...	136	166	229	
1822	107	71	92	...	96	115	104	106	116	118	121	...	120	152	207	
1823	128	97	109	...	114	136	121	130	*146*	143	...	...	140	168	227	
1824	132	106	120	...	118	140	123	137	145	147	...	...	148	172	229	
1825	119	86	102	...	104	126	110	122	*137*	137	...	...	123	161	213	
1826	119	89	103	...	105	127	111	122	*138*	137	...	...	131	162	206	
1827	125	92	108	...	110	134	119	133	*142*	139	...	...	137	165	214	
1828	117	87	100	...	104	126	110	122	134	136	137	103	127	165	212	
1829	129	103	114	...	117	138	123	135	140	142	142	110	141	164	219	
1830	112	84	97	104	98	121	108	112	124	126	128	99	124	155	219	
1831	121	91	105	120	108	128	112	124	139	142	143	105	135	160	210	
1832	127	95	110	123	114	137	116	127	144	144	145	110	140	164	214	
1833	125	105	109	124	113	134	120	126	135	137	137	109	137	158	215	
1834	119	76	106	117	106	130	110	123	130	128	128	106	132	156	202	
1835	127	92	110	127	113	135	120	135	139	141	143	110	144	160	212	
1836	130	108	113	128	119	137	123	134	141	147	148	111	148	171	214	
1837	138	115	124	137	122	141	134	145	152	153	156	113	156	173	227	
1838	128	101	120	124	114	130	122	128	136	145	142	115	146	169	226	
1839	125	106	117	120	113	125	118	123	136	139	140	115	144	163	221	
1840	114	93	109	111	107	117	112	115	120	122	122	105	121	153	217	
1841	104	75	91	104	86	117	91	105	120	121	121	107	121	147	219	
1842	106	87	92	112	87	117	91	114	124	127	126	109	126	149	213	
1843	105	82	92	107	90	110	94	110	121	124	123	105	123	153	220	
1844	107	88	99	107	95	107	100	107	117	118	118	101	122	150	213	
1845	124	108	115	120	113	120	113	119	138	137	138	110	145	161	226	
1846	100	57	89	72	85	97	87	102	118	126	118	99	121	149	199	
1847	129	101	115	118	111	137	130	131	147	154	152	111	135	150	211	
1848	111	89	93	95	94	121	94	95	136	141	138	108	128	144	220	
1849	117	89	97	118	101	120	97	120	151	151	150	106	136	156	214	
1850	121	93	109	108	99	119	107	109	149	149	149	103	142	154	212	
1851	124	86	108	110	108	137	108	132	143	143	144	105	141	155	217	
1852	122	88	118	102	105	134	102	124	137	138	137	105	134	160	218	
1853	127	106	120	120	109	136	109	138	144	145	146	110	144	160	222	
1854	105	74	92	83	96	111	88	98	121	132	125	96	124	152	220	
1855	131	107	123	129	114	140	123	138	142	143	144	118	146	167	229	
1856	121	93	99	102	99	138	106	116	141	142	141	115	142	156	219	
1857	109	80	92	91	94	109	91	108	133	138	135	106	135	154	205	
1858	118	83	109	105	105	112	110	110	138	140	135	109	133	157	...	
1859	95	62	75	75	79	96	73	94	127	135	131	96	123	149	...	
1860	129	106	122	113	107	138	123	130	140	140	142	119	144	168	...	
1861	119	77	106	106	95	137	94	122	139	141	141	106	141	164	...	
1862	105	71	95	100	93	105	91	110	124	124	124	106	125	146	...	
1863	107	64	98	95	93	105	98	108	129	129	129	103	122	149	...	
1864	119	77	111	105	109	118	109	118	136	136	141	110	131	150		
Average of all Records	119 Apr. 29	80 Mar. 30	105 Apr. 15	109 Apr. 19	104 Apr 14	125 May 5	108 Apr. 18	120 Apr. 30	135 May 15	137 May 17	136 May 16	107 Apr. 17	134 May 14	158 June 7	216 Aug. 4	

* Mean of sycamore, horse-chestnut, maple, willow and oak leafing and hawthorn flowering.

† In Suffolk generally.

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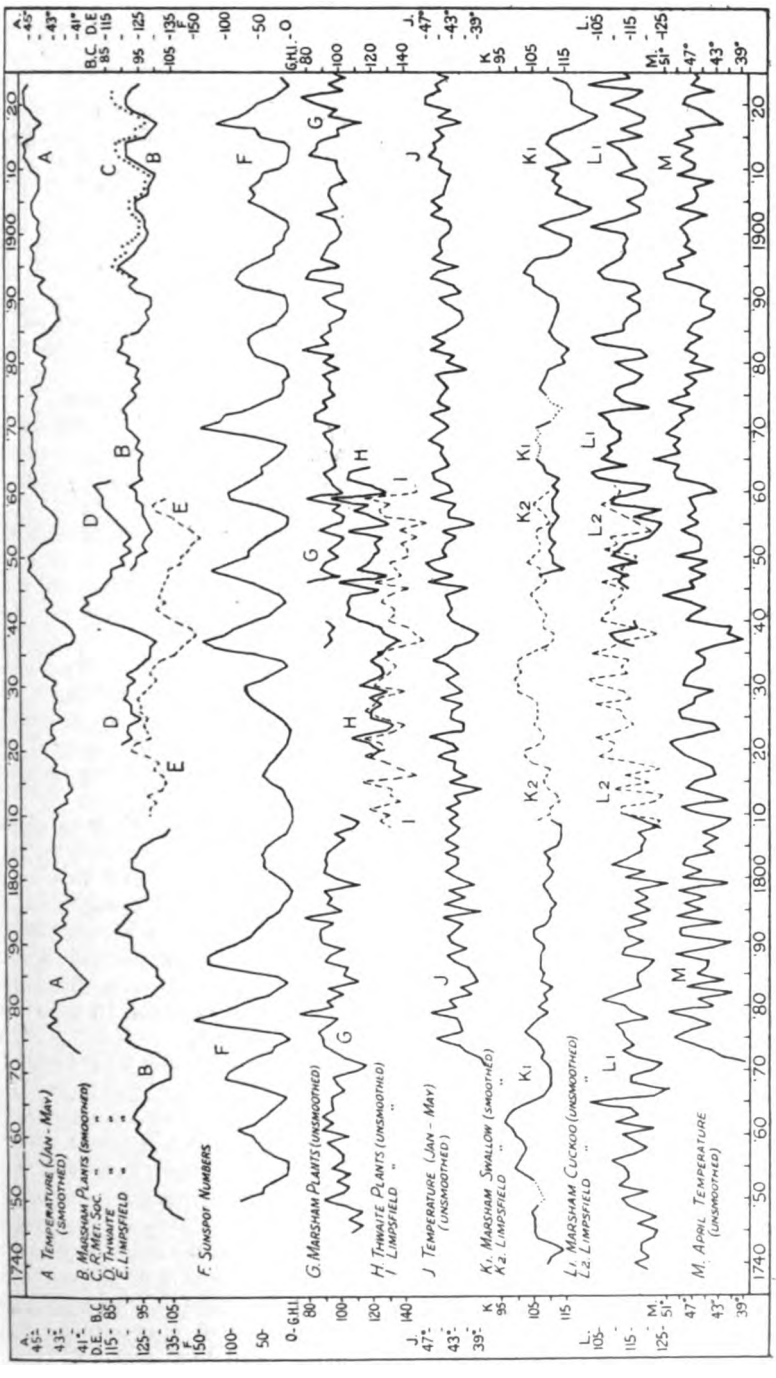

FIG. 3.—The Marsham record, etc., showing periodicities and temperature relations.

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Plants.

For the plants, the annual means of the seven plants, previously shown to be fully comparable with the Society's series were obtained for all available years. They are given in Table I. and shown graphically in Fig. 3 (Curve G). A glance at this graph shows that the annual fluctuations are large, the extreme range being 42 days, but it is also quite evident that the notably early or late years occur at regular intervals. That this should be so clearly shown by unsmoothed observations of this character is surely very significant.

This periodic tendency is brought out more clearly by smoothing, and the result of bloxaming the annual values in fives (*i.e.*, the value for 1920=(1918+'19+'20+'21+'22)÷5, and so for each year) is also given in Fig. 3 (Curve B). A very distinct periodicity is shown.

It should be noted that the Thwaite and Limpsfield plant records (Fig. 3, Curves H and I unsmoothed, D and E smoothed) are in very good agreement (as regards annual tendency) with the Marsham values throughout the overlapping period, and show the same periodicity. No attempt has been made to interpolate values from them to fill the Marsham gap, but they do at least provide the dates of extreme epochs during the missing years.

A summary of the extreme years, for both smoothed and unsmoothed values, is given in Table VI., where it will be seen that the mean period is 12.2 years (unsmoothed), or 12.1 years (smoothed), between either the early years or the late years.

The smoothed curve presents some very definite features, the chief being a subsidiary minimum (late year) immediately preceding the maximum (or earliest year), which occurs in ten out of the fifteen periods available. The similarity of the three periods covering the years 1758-1798 is especially remarkable.

That temperature is an important factor in relation to plants is of course well known, and it was particularly important to have a long and reliable temperature record for comparison with this work. Fortunately Mr. Jas. Glaisher[7] had made a careful comparison of London mean temperatures from several old records with the Greenwich series, enabling the latter to be extended by comparable figures from 1841 back to 1771. All remarks on temperature in this paper refer to this record of mean temperature, which is (back to 1841) the mean of the 24 hourly readings.

The annual mean of the Marsham seven plants was found to vary in close agreement with the mean temperature for January-May (the corresponding period); indeed the agreement is so close, with few exceptions, that it seems clear that temperature must be the chief controlling influence, at least, at that season, rain and sunshine affecting the plants less directly. This comparison is available for 123 years, and if the means of the seven plants are grouped according to each 1°F. of the five months' mean temperature, and the average date of each group obtained, it is clear that the earliness of the plants is proportional to the temperature. These average values are plotted on Fig. 4, which indicates an approximate relation of five days' advance for each 2°F. mean temperature.

[7] *Phil. Trans. R.Soc.*, 1850. 2 papers.

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Mean Temp. (Jan. – May).								Marsham 7 Plants.								Sunspot Numbers.			
Unsmoothed				Smoothed.				Unsmoothed.				Smoothed.							
Coldest.	Interval.	Warmest.	Interval.	Coldest.	Interval.	Warmest.	Interval.	Latest.	Interval.	Earliest.	Interval.	Latest.	Interval.	Earliest.	Interval.	Minimum.	Interval.	Maximum.	Interval.
...		...		...		...		1746		1750		1747		1751		...		...	
	...		...		...		...		14		13		8		12		...		...
...		...		...		...		1760		1763		1755		1763		1755		1761	
	...		...		...		...		11		16		15		14		11		8
...		...		...		...		...		..		...		...		1766		1769	
	...		...		...		...		...		...		...		...		9		9
1771		1779		...		1777		1771		1779		1770		1777		1775		1778	
	13		15		...		15		13		15		14		15		9		10
1784		1794		1784		1792		1784		1794		1784		1792		1784		1788	
	15		10		13		13		15		7		13		10		14		16
1799		1804		1797		1805		1799		1801		1797		1802		1798		1804	
	15		18		17		15		17		21		18		18		12		12
1814		1822		1814		1820		(1816)		(1822)		(1815)		(1820)		1810		1816	
	10		12		11		13		8		8		10		8		13		14
1824		1834		1825		1833		(1824)		(1830)		(1825)		(1828)		1823		1830	
	14		15		13		15		13		16		12		14		10		7
1838		1849		1838		1848		(1837)		1846		(1837)		(1842)		1833		1837	
	17		10		17		13		16		13		17		19		10		11
...		...		...		...		...		...		...		...		1843		1848	
	...		...		...		...		...		...		...		...		13		12
1855		1859		1855		1861		1853		1859		1854		1861		1856		1860	
	9		9		10		9		11		12		12		12		11		10
1864		1868		1865		1870		1864		1871		1866		1873		1867		1870	
	15		14		14		13		15		11		11		9		11		14
1879		1882		1879		1883		1879		1882		1877		1882		1878		1884	
	9		11		8		12		9		11		12		13		11		9
1888		1893		1887		1895		1888		1893		1889		1895		1889		1893	
	13		10		13		10		12		10		11		9		12		13
1901		1903		1900		1905		1900		1903		1900		1904		1901		1906	
	8		9		9		7		8		9		9		9		11		11
1909		1912		1909		1912		1908		1912		1909		1913		1912		1917	
	8		8		8		9		9		9		8		8		11		...
1917		1920		1917		1922		1917		1921		1917		1921		1923		...	
Means	12.2		11.8		12.1		12.1		12.2		12.2		12.1		12.1		11.2		11.2

Bracketed dates are derived from the Limpsfield and Thwaite records.

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Correlation coefficients were also obtained between the seven plants and five months' temperature. For the 35 years 1891-1925 the value is −.82, but for the full 123 years it is only −.61. This lower value is apparently due to a gradual and persistent rise of temperature which becomes appreciable when such a long period is considered. When the annual deviations of temperature from the general average were obtained for the correlation it was found that negative deviations preponderated to a marked degree prior to 1840, while the positive deviations were equally in excess during the latter half. The plant dates do not show this so clearly, and the correlation coefficient for the longer period is consequently lowered.

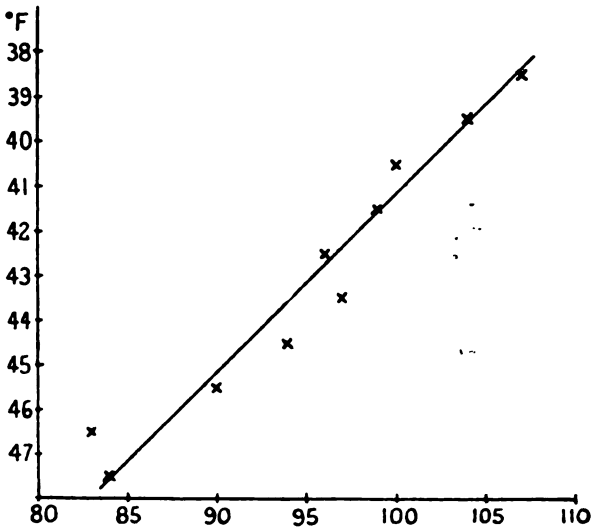

FIG. 4.—Proportionality of plant dates with temperature. (The straight line indicates a relation of five days for each 2 deg. F.)

The annual values of the five months' temperature are plotted on Fig. 3 (Curve J unsmoothed, A smoothed), where the agreement with the plant values (including those of Limpsfield and Thwaite) should be noted. It may be of interest to record that Mr. Marshall, who had been working on the Glaisher temperature record, and very kindly supplied me with a copy of the monthly means, was in some doubt as to the accuracy of the temperature values before 1800, since they showed larger fluctuations than in the later years, and no other means of checking them was then available. The Marsham plant records showed, however, that the variations were fully justified.

It is evident that the temperature curve does not show such a clear periodicity between extreme years as does that of the plants, but when the epochs of the plant curve are known, those of temperature can be more clearly followed. By smoothing as before, a definite period averaging 12.1 years is brought out. The extreme years of these temperature periods are also given in Table VI., and should be compared with the corresponding values for the plants. The years of epoch are in close agreement. The value of

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phenological observations is well illustrated by the fact that this periodicity is more clearly shown by plant dates than by temperature records.

It was thought worth comparing these periods with those of sunspot frequency, and the sunspot values were accordingly inserted in Fig. 3 (Curve F). It will be seen that there is a general tendency for the epochs of early years and spot *maximum* to be either in good agreement, or, in a few cases, in exact opposition. For so long a period as 1848-1909 the smoothed plant curve would fairly justify belief in a moderate sunspot connection; indeed for the years 1871-1905 the *unsmoothed* means of the Marsham seven plants gave a correlation of −.49, yet from 1910 all agreement in this sense seems at an end. The most remarkable epochs of opposition were in 1770, 1815, 1837 and 1917, when late years occurred at spot *maximum*.

The relation of temperature and sunspots has already received much attention. Nordmann[8] studied the data for 1870-1900 and found the sunspot frequency and mean annual temperature closely related, a result which shows the risks of using a relatively short period. Huntingdon[9] refers to work done by Abbot and Fowle[10] in comparing terrestrial temperature and sunspots back to 1750, and remarks that a clear *rise* of temperature with scarcity of sunspots is shown, although this is less evident in the earlier years "presumably because the records are few and imperfect." He also quotes Humphreys[11] as saying that "at least since 1750 . . . and presumably therefore since an indefinitely distant time in the past, the two phenomena, atmospheric temperature and sunspot numbers, have in general varied together, with however marked discrepancies from time to time." Humphreys' view seems in general agreement with the results shown here, but in the light of the recent discrepancies about 1917, it seems impossible to ascribe such cases in the early years to imperfect observation.

That these workers found even a moderate connection between temperature and sunspots in a sense directly opposite to that shown here is somewhat surprising, but it must be remembered that we are dealing with the months January to May and not the whole year, a fact which might possibly throw some light on the whole problem.

It is at least clear that the mean temperature of January to May and the dates of these plant events do show an apparent connection of warmth and earliness with sunspot *maximum* nine times out of fifteen, and of lateness with spot minimum to the same degree. Yet an exactly opposite relation is shown at the epochs of 1770, 1815, 1837 and 1917, and this is evidently not due to any gradual "out of step" effect of two curves of different period, but occurs suddenly, only a wave length from complete agreement.

Birds.

Looking at the bird records over the whole period, the regularity of arrival of the cuckoo in comparison with the swallow is most

[8] Ch. Nordmann. *Sunspot Period and Variations of Mean Annual Temperature of the Earth.* Reprinted from *Revue Genle. des Sciences*, August, 1904. *Smithsonian Report*, 1903, pp. 139-149.
[9] Ellsworth Huntingdon. *Earth and Sun*, pp. 10-12.
[10] *Smithsonian Misc. Coll.*, **9**, No. 29, 1913.
[11] W. J. Humphreys, *Physics of the Air*, 1920, p. 598.

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noticeable. The two should be compared in Fig. 2, not in Fig. 3 where the *smoothed* swallow curve only is shown. The cuckoo dates for the full period are plotted on Fig. 3 (Curve L), and it will be seen that its yearly fluctuations agree to some extent with April temperature (Curve M), but the agreement is far less close than that shown by plants. Very possibly the temperature of a much shorter period, say the week of arrival, would give better results.

The swallow seems much more erratic in its arrival dates and shows no relation with April temperature at all. If the yearly dates are smoothed by bloxaming in threes a curious periodic tendency appears. This is shown in Fig. 3 (Curve K). It is particularly marked since 1890, but is clearly traceable throughout the whole record (including that of Limpsfield) back to 1740. The average length of the period is 7.6 years. No similar effect is shown by the cuckoo, and the Society's series of mean dates for the swallow do not show it clearly, possibly because, being district means, they are already more smoothed. The differences in character thus shown by the swallow and cuckoo, both insect-eating migrants, is interesting.

The nightingale's variations seem rather similar to those of the swallow, but the curve cannot be properly followed owing to numerous small gaps in the record.

Averages.

Nothing has yet been said of the averages of the separate observations. These are given at the end of Table I. for each decade and for the first and last available 35 years, together with the general averages of all the observations in the record.

The decade averages vary considerably, especially for the plants, and it will be found that this is due to the periodicities described above, the average of a decade centred about an early epoch naturally being earlier than one coinciding with a late epoch. For instance, Southwell, in his first paper, made a comparison of the observations for the ten years ending 1774 with those of the decade ending 1874, and concluded from this that the springs were definitely getting earlier. We now see that the first decade centred round a particularly late epoch, while the second contained an early epoch.

The averages for the two 35-year periods are more significant. Comparing the two, it is found that 10 out of the 16 plants (omitting turnip as artificially influenced and unsuitable) were earlier in the second period, three were unchanged, while only three were later. It may surely be said that this shows at least a tendency to earlier springs in recent times. The averages of other 30-year periods close to these dates, carefully chosen to contain equal proportions of early and late epochs, gave identical results, which shows that this earlier tendency was not due to a chance over-weighting by early years.

As to the birds, these show very little change in the two 35-year periods, with the notable exception of the swallow, which is later by eight days in the last period. This is a remarkably large variation, and in an unexpected direction. The decade averages suggest that the retardation has been increasing gradually throughout the whole

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record, a valuable result, and possibly an indication of some definite climatic change at its winter quarters.

The general averages for the Limpsfield and Thwaite records are given at the foot of Tables IV. and V. Compared with the Marsham general averages the Thwaite records of leafing are decidedly late, the difference for the six plants common to both series averaging 16 days. Yet the averages for hawthorn flower are in good agreement. The most probable explanation is that Whistlecraft noted the date of *full* leafing, in contrast to the Marsham practice of observing the earliest commencement, so that the two series provide useful comparisons on the development of leafing. Again, Cox's Limpsfield average date for hawthorn flower is a fortnight later than those of the other records, due most likely to a similar difference in observational practice. The bird averages are in good agreement, the earlier tendency of the Limpsfield record clearly being due to its more southern position.

Forecasts.

Finally it is of interest to see whether the plant periodicity is likely to be of use in forecasting the character of future springs. Of course the curve is far from regular, but judging by the final portion of it as shown in Fig. 3 (Curve B), it seems probable that the bloxamed value to be inserted for 1924 will be near 97. To obtain such a value would require the mean for the Marsham seven plants in 1926 to be 89 (March 30). Moreover the five months' temperature curve suggests that the bloxamed value for 1924 would probably be 44°.8, and this would require the actual mean for 1926 to be 45°.0, or practically equal to that of last year. From Fig. 4 it will be seen that 45° is equivalent to the plant date 89, a corroborative result.

A mean of 89, then, indicates for 1926 a spring intermediate as regards the plants between 1920 and 1923, and therefore somewhat early. But it must be remembered that a variation of five days from this value only affects the *bloxamed* figure by one day, so that the method only gives a general indication. Even so, it seems capable of more extended use.

Looking further ahead, it seems certain that the bloxamed curve is approaching another minimum. This might occur in the *smoothed* value for 1925, but that would make the last period since the previous minimum in 1917 very short (eight years) for the third time running, and it is more probable that it would be at least two years later. If the *actual* mean for 1926 proves to be 89, as suggested, then that for 1927 would have to be as late as 108 or April 18 (a very late value, only exceeded in recent years by 1917 with 114), in order that the bloxamed value for 1925 (98) should be later by only one day than that for 1924 (97).

Thus it seems probable that the spring of 1926 will be rather mild and early, but that of 1927 decidedly cold and late. It will be interesting to see how far these conditions are fulfilled.

The main object of this paper has been to introduce this remarkable record in a useful form, to show its relation to the Society's Reports and to point out some of its main features. That there is much for other workers to do in throwing more light on the points

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raised, and in going more deeply into specialised sections of the record is evident.

I wish to record my sincere thanks to Dr. H. R. Mill, Mr. J. E. Clark and Mr. R. Marshall for their help in supplying me with comparative data and valuable criticism, and also to all those who, by their willing help in the early stages of the work, alone made this investigation possible.

DISCUSSION.

Mr J. E. Clark said he would like to point out that the Phenological Committee were finding that there was more value than had been expected in the records of migrant birds such as were contained in Mr. Margary's paper. For instance, they had found that they could correlate them with plant records, and already very much work had been done in making use of such plant phenology as this in connection with agriculture. In the Phenological Report which has just appeared they had taken advantage of the possibility of correlation between migrants and plant records for getting probable dates for birds in the north country where actual records were very scarce, conversely it was a very important thing to determine that, whilst there were blanks in a given number of plants in a certain record and in another record some were found which did not correspond, bird records made it possible to fill in the gaps in the plant records especially as some of the bird records are much more reliable and consistent. In recent articles in *Nature* it was shown that it was easy to discover data to cover the whole of Europe in this way. He had in his possession a very interesting series of observations on the cuckoo made in Russia, with isophenes. He had learned too, from Dr. J. Schenk, of Budapest, that he was devoting himself very specially to the cuckoo, because its records were very much more regular than any others. Thus again, the cuckoo made transference of records of agricultural phenomena in one part of Europe to others possible. He would also like to emphasise the fact that there were records about the country which would be of immense value if they could get hold of them. He had a series of records for about the year 1756, made in the neighbourhood of Limerick covering six years, mainly weather records, with some agricultural and some ordinary phenological notes, but still, he thought, of considerable value, of which he was getting copies by degrees from a descendant of the observer. He had also another one dating from 1870, and thus going back rather further than the records of the Society. It was a series for the east of England, mainly Cambridge and Nottingham, and contained the records of over 200 plants with the dates of their appearances. That was the kind of record that could not be done universally, but if only one such record came into the hands of experts, it might very well be found to give many really valuable particulars for correlating one series of records with another.

Mr. H. Mellish asked Mr. Margary if he had seen the registers kept at Burnham in Norfolk for 40 years, which came into the possession of the Society a few years ago, and which, though primarily a record of temperature and rainfall, contained a considerable number of systematic phenological observations.

Dr. G. C. Simpson said he wished to congratulate Mr. Margary on the piece of work he had done, and also on the excellent manner in which he had brought it before the Society. He found from the paper that the records of plants confirmed the temperature observations at Greenwich, which was rather an important fact and also very valuable. In regard to the Greenwich temperatures, there were no tests either of

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exposure or of instruments in use in the earlier times. The correlation was extremely high between the Greenwich temperatures and the records of plants, and there could be no doubt that the variation was quite real.

Mr. R. MARSHALL said that as Mr. Margary had told them, he was responsible for one of the curves shown in the paper, and he would like, therefore, to point out one thing with reference to it. From 1841 onward the curve was based on the ordinary Greenwich temperatures, *i.e.*, the means of the 24-hourly readings each day. Previous to that, it was from Mr. Glaisher's figures from 1841 backwards. Mr. Glaisher took records kept at four or five places round about London; Epping, Stratford, Chiswick, etc., also the Somerset House record and worked them together. The value for Greenwich was obtained by putting together all these records, getting rid of unlikely readings, working out monthly means, and finally reducing the result to 159ft. above sea-level. The part of the curve on the diagram from 1771 to 1841 represented these values, but he (the speaker) thought them all 1°F. to 1°.5 too low, hence the first part of the diagram was on a lower level than the last. The early Greenwich record began about 1807, noon readings only; by 1814 these had increased to four readings per day, but not until 1841 was the official record published. Mr. Glaisher's figures were published in 1850 when the official record had been running about 10 years only, so that any error in his computation was not apparent. But now, 75 years later, it was evident that Mr. Glaisher's values were too low. The speaker had also been doubtful about the extremely large ups and downs of the early part of the curve, but was now pleased to see them so strikingly confirmed by Mr. Margary's other curves; and if the 1°.5 plus correction were applied to the temperature curve from the beginning to 1840 one would get a still closer agreement and a better correlation.

Mr. R. H. HOOKER congratulated Mr. Margary and his helpers, and appreciated the great value of a record of such a long period. With regard to the coefficients of .8 and .9 obtained by correlating the Norfolk observations with the Society's for such periods as were available, he would have been extremely astonished if these had been smaller. The individual station would naturally show much similarity with the surrounding area, and he would regard any smaller coefficient as evidence of very careless observations He did not attach much importance to the evidences of periodicity which the author deduced from the diagrams. Some of the oscillations certainly seemed to be visible, but he wished to point out that the determination of periodicity was not to be deduced from mere inspection of such curves, especially when they had been smoothed or "bloxamised," a process which was liable to produce a false appearance of oscillation. He was not prepared to deny the existence of periodicity in these phenomena, but he could not see that the author had proved any.

Mr. L. C. W. BONACINA said that in regard to the dates of the cuckoo not corresponding very well with the temperature of April, it had been shown in America that the strength of the sunlight in stimulating sex-impulse is a more potent factor in bird migration than temperature, and he thought that this probably accounted for the discrepancy. He was struck by a slide in which wood anemone did not tally very well with the hawthorn. He thought that in the case of herbaceous plants which characteristically grow in close association, there was fierce competition between the various species and individuals, and that the œcological factor was consequently apt sometimes to override the climatic. He

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also thought that there was another factor which had not been brought out, and that was the cumulative effect of the previous year's conditions on the phenological dates. A plant may be early one year on account of some complicated effect of the totality of the atmospheric elements during the previous season.

Mr. C. E. P. Brooks said that he had worked out a rough periodogram from the data given by Mr. Margary, and found that there was a periodicity of 14 or 15 years, but not very well developed. This result was of interest because it came near the periodicity of 15 years found by Sir William Beveridge in wheat prices.

Dr. Harold Jeffreys thought that the value of the paper might be increased if more definite indication were given as to what species of plants were dealt with. In East Anglia there were two species of hawthorn, three species of birch, several of elm, two of oak and three of lime. He thought it would be much clearer if they were told which species were referred to. There was an extreme case of this uncertainty in the Society's phenological record. It included the dog-rose; it required very special attention to the genus *Rosa* before one could identify *Rosa canina* (botanists regarded it as an extremely difficult genus), and he did not know how many of the Society's observers had given such attention to the matter.

Mr. I. D. Margary, in reply, said he was aware of the existence of the Burnham record, but had not referred to it because he did not want to overload the paper. The question of the relation of the Greenwich temperatures was a very interesting one. As regards the correlation coefficients, he had worked them out for what they were worth, but they were not intended to have more weight put upon them than they ought to bear. As regards the periodicity, as Mr. Brooks had discovered a periodicity of about 15 years, he concluded that since there was certainly an apparent periodicity of 12 years there must also be other periodicities. As to the value of this periodicity, he did not want to lay more stress upon it than the record warranted, but it did show itself very frequently even in unsmoothed values, by a return to similar conditions at the end of 12 years. In regard to Dr. Jeffreys's criticism, it was impossible to tell at this time what were the exact species observed by the earlier workers in this record, but since they observed the *earliest* specimen, it would probably be the most forward species. Because there were no means of discovering exactly what species the earlier generations observed, he had purposely refrained from using Latin names in the paper. The case of the dog-rose in the Society's list was found not to give rise to difficulty in practice, the dates of flowering of the different species being apparently very similar. He would very much like to see further work done on the record, and there was plenty of work in it for someone else. He would like to suggest one or two points such as a more detailed examination of the periodicity, and another interesting thing would be to try shorter periods at different seasons for which plant records were available, and see what the results would be at different times of the year. The curve for the plants clearly shows more sensitiveness under extreme conditions than the curve of the temperatures. The temperature curve was not so erratic as the plant curve, and plants would appear to be better than a thermometer for indicating extremes. He would like to know why the temperature relationships sometimes broke down. Another point was about the birds; why the swallow should be getting later in arriving, and be more erratic than the cuckoo, since both are insect-eaters and so dependent on a similar food-supply, though possibly not the same species of insect.

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EXPERIMENTS ON THE SHIELDING OF RAINGAUGES.

By C. D. STEWART, B.Sc.

[Received August 21—Read December 16, 1925.]

The measurement of rainfall is probably the simplest of all quantitative meteorological observations so far as the skill demanded of the observer is concerned, but it has long been realised that the accurate reading of a raingauge is by no means the same thing as the accurate measurement of rainfall. It may safely be asserted that, except on occasions of zero wind speed, any raingauge as ordinarily mounted and exposed will register less rain than actually falls; but in the absence of any suitable standard of comparison it is impossible to say by how much the catch in any particular instance falls short of the full amount.

The chief cause of deficiency, the only one, in fact, of which account will be taken in the present discussion, is wind. Eddies set up by the projecting portions of the gauge are sufficient to deflect from the gauge drops which would normally be caught, and at times these may even be strong enough to eject drops which have already entered the funnel. On the other hand the gauge gains a certain amount from the fine spray caused by the splashing of drops on the ground round about, and in some situations spray from adjacent water surfaces and drops of water blown from trees may introduce an element of uncertainty into the records.

The causes of error in raingauges have been discussed by several writers and a convenient summary of the phenomena may be obtained by reference to the *Encyclopædia Britannica* (10th Edition), where the subject is referred to in the articles on Meteorology and Water Supply.[1]

Long experience has proved that, other things remaining the same, a raingauge at a height will register less than one lower down, owing to the greater wind speed usually found at the higher altitude; the differences in some cases are very striking. Even with the raingauge rim at a height of only one foot, as in the standard British exposure, the effect of wind is still appreciable. It is hardly practicable to reduce the height of the gauge for normal use, so that the only possible measure to be taken to minimise wind effects further is to shelter the gauge in some way from the wind without at the same time guarding it from the rain. We have no means of knowing precisely how near we may be approaching to the true rainfall with any system of shielding, natural or artificial, but we may by experiment succeed in effecting definite improvement in rainfall measurements even though we still leave them imperfect.

It is sufficiently evident that proximity to buildings or hedges will result in a certain amount of shielding for a gauge, but it is equally obvious that for some wind directions the gain by shielding may be more than counterbalanced by rain being shut off directly from the gauge unless the distance is properly selected. It has been laid down, therefore, that for the exposure of a gauge to be

[1] See also an article by E. Gold in the *Meteorological Magazine* for October, 1922.

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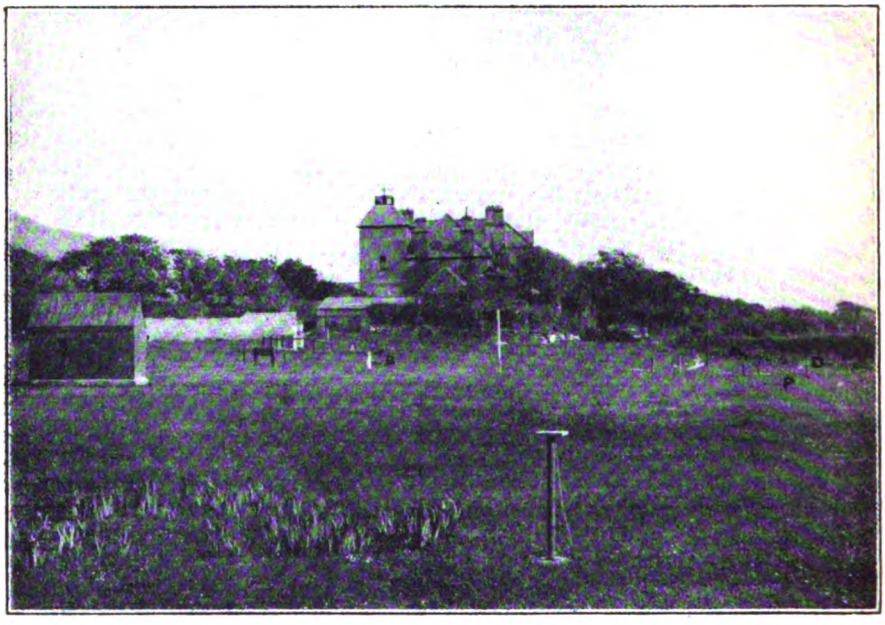
accepted as standard any building, tree or other obstacle must be at a distance of at least twice its height from the gauge. There is the further possibility that special devices at the gauge may be effective in decreasing the loss due to eddies; such are the conical shield (Fig. 2) devised by Professor Nipher and the surrounding pit for a gauge, first used many years ago, fresh experiments with which were suggested more recently by E. Gold (Figs. 3 and 4).

The possibilities of these different methods of eliminating wind effects at a gauge can only be determined by experiment. The study of the variations in the records from a shielded gauge as compared with one which is not shielded in different wind conditions seems to promise results which will certainly be of considerable interest



Photograph showing Valencia Observatory with instruments in position. (See sketch plan.)

and may prove to be of some value practically. The present paper is an account of some investigations of this nature carried out at Valencia Observatory. The Observatory is provided with a number of raingauges available for experimental purposes, some of which are self-recording instruments. The advantage of autographic records in an inquiry such as this lies in the facility with which falls of rain can be separated into portions to which can be assigned the appropriate wind direction and speed, an operation not usually feasible with the whole day's rainfall as measured with the ordinary type of gauge. Valencia is an unusually good station for rain-gauge experiments on account of the amount and duration of the rainfall experienced, these two factors combining to give records from which reliable information can be gained in a comparatively short interval of time.

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The arrangement of the raingauges at Valencia Observatory during the period of these experiments is shown in Fig. 1, which is a sketch map of the Observatory and its surroundings. This map, while not absolutely accurate in all details, is nevertheless sufficiently so to give a true idea of the exposures of the different instruments. The scale at the foot indicates the general propor-

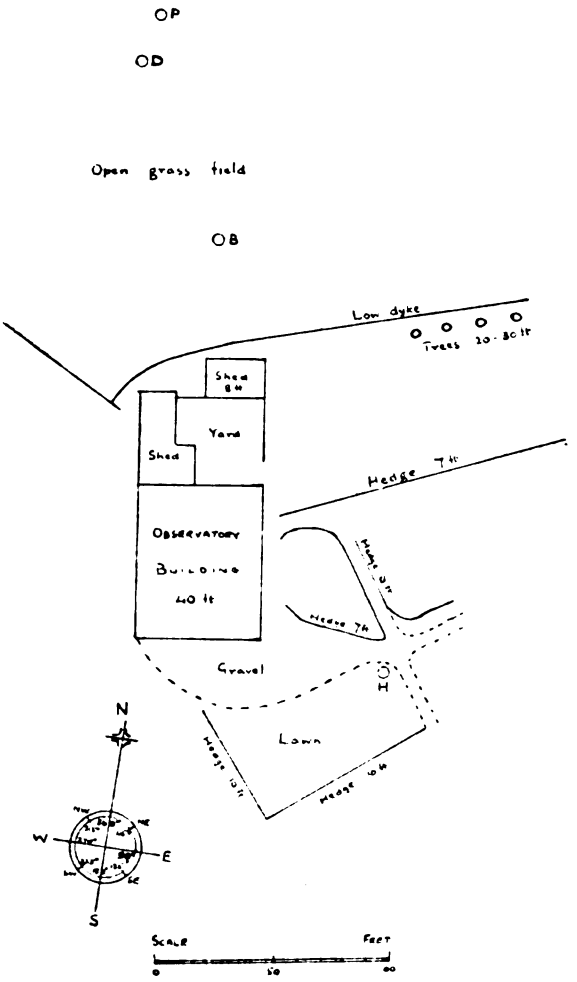

FIG. 1.—Sketch plan showing the sites and surroundings of the raingauges at Valencia Observatory.

tions of the drawing, but not short lengths such as the width of a drive. The photograph, when considered with the map, will be found to assist considerably in giving a conception of the exposures of all the gauges except the one marked H in the map, which is behind the building in the photograph. The marks on the photograph correspond with those on the map.

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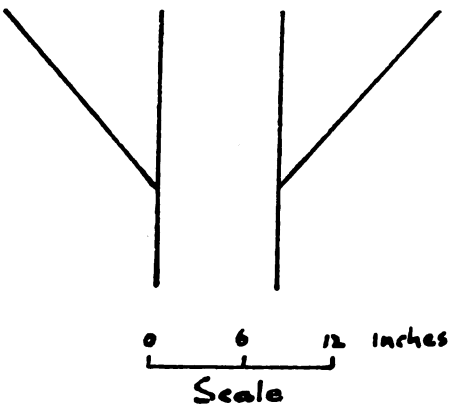

FIG. 2.—Nipher Shield as used at Valencia Observatory.

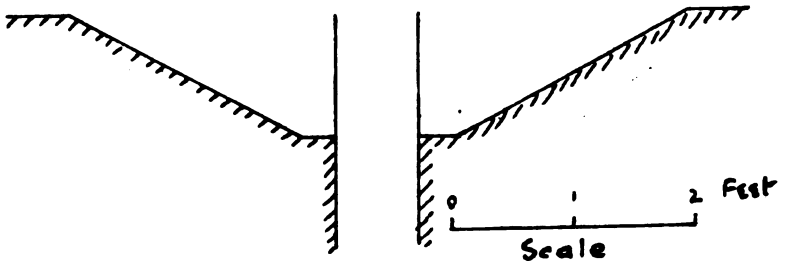

FIG. 3.—Pit with sloped sides.

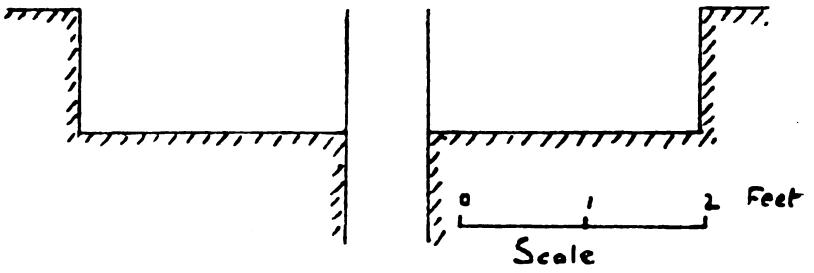

FIG. 4.—Pit with vertical sides.

The heights of all surrounding objects are given at their map positions. The instruments indicated by the different circles are as follows :—

H Hyetograph, height 18in., funnel 6in., self-recording.

B Beckley Gauge, height 22in., funnel 11½in., self-recording.

D Dines Gauge, height 29in., funnel 8in., self-recording. This gauge was used as thus defined from January, 1921, to the middle of February, 1922. From the latter date it had attached a Nipher Shield, of which the details are given in Fig. 2.

P Standard M.O. Gauge, height 12in., funnel 8in., not recording. This gauge was used in the ordinary way, with its rim one foot above the ground, from February, 1921, to January, 1922; in a conical pit with details as in Fig. 3 from February, 1922, to January, 1923; and in a vertical walled pit with details as in Fig. 4 from February, 1923, to April, 1924.

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The records from all these gauges have been practically continuous so that a considerable amount of data is available for studying the effects of the different types of shielding. The differences in site exposure and in the heights and other dimensions of the gauges introduce some complications into the comparisons, but the methods of treatment have been so chosen as to eliminate effects due to these differences. It is obvious that the study of shielding effects due to buildings cannot be carried out by direct methods such as are possible in the study of the shielding due to pits and the Nipher Shield, and it is inevitable that the results obtained in the former case should be of a less definite character than those in the latter.

I. Shielding Due to Buildings.

Under the head of buildings we include trees, hedges and the slope of the ground in so far as this may have any effect; and in general this section may be supposed to consider permanent geographical features as distinct from the controllable instrumental modifications which are dealt with in later sections. Reference to the map, Fig. 1, will show that the gauges H and B lie on a line running, roughly, from south-east to north-west with the building touching the line and lying on the westerly side of it. Both gauges conform to the standard condition that all surrounding objects shall be at distances not less than twice their heights. The lawn surrounding the hyetograph is fairly level, while the field with the other gauges has a fairly uniform downward slope of approximately 1 in 20 to the north-west. We shall first compare the records from the two gauges, H and B.

The method adopted in dealing with the records was to enter corresponding rainfalls from the two gauges in parallel columns with the appropriate wind speed and direction for each fall in a third column. The entries were then analysed according to speed and direction of wind, the totals being afterwards combined in one table. The winds are taken from the tabulated hourly values of the Dines Pressure Tube Anemograph and are of necessity only a fairly close approximation for each fall since no attempt was made, for example, to obtain a true weighted mean according to the amounts of rain which fell in each hour. No attempt was made to reduce wind speeds at the anemometer to ground level. It would appear at first sight that with two recording raingauges the simplest plan would be to make hourly tabulations of rain from each gauge and then to insert the corresponding hourly values of the wind. This was, as a matter of fact, the method adopted at first, but it soon became evident that uncertainties in the clocks, accentuated by the effects of the swelling of the paper in the damp air, would make the labour necessary to secure even approximately accurate synchronism absolutely prohibitive. Even with the amount of care represented by about twenty minutes spent on the curves for one day with 30 millimetres of rain, it was quite plain in the result that the rain entries for the two instruments did not correspond. When it is realised that 2,000 curves had to be examined and tabulated, it will be sufficiently obvious that progress by this method would have been altogether too slow. The alternative adopted was to deal with continuous falls. Corresponding traces show quite clearly

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the times of commencement and cessation of each fall. If, as frequently happened in the case of prolonged rainfall, the wind was not approximately constant during the whole of the fall, well-marked points of inflection in the curves would often enable corresponding times to be identified so that the fall could be divided into sections, each of which had a more or less constant wind. There were occasions, however, when even this amount of segregation was not possible and the mean speed and direction of the wind had then to be computed for the fall as a whole, those portions of the period during which the rain was falling most heavily being given most weight. As stated above, no attempt was made to obtain an accurate weighted mean. As a rule the mean wind could be written down directly from the tabulations after quite a brief inspecton, even though the period under consideration covered some hours. It was inevitable that some rainfalls should be entered against a wind which was the mean of values with a very wide range both in direction and speed; in one case the direction varied from South to North-west and the speed from 5 to 13 metres per second, but as a rule in the case of large wind fluctuations it was possible to divide up the falls as indicated above.

The analysis of the corresponding records for H and B is given in Tables I. and II. The period covered is from January, 1922, to March, 1924. Table I. gives the corresponding total fall measured by each gauge for the different winds, and Table II. the ratio Hyetograph catch/Beckley catch computed in each instance from Table I. The ratios placed within brackets are less reliable than those not so marked owing to the small quantities of rain which are concerned. Wind directions are given both as compass bearings and in degrees measured clockwise from true North.

TABLE I.—Analysis of Rainfall measured by the Hyetograph (H) and the Beckley Gauge (B) according to Winds.

Speed m/s	SE (135°)		S (180°)		SW (225°)		W (270°)		NW (315°)		Totals.	
	H.	B.	H.	B.	H.	B.	H.	B.	H.	B.	H.	B.
	mm.	mm.	mm.	mm	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
3	13.1	14.2	10.0	10.3	32.0	34.0	33.2	32.0	43.8	43.8	141.1	144.8
6	60.1	63.7	82.3	84.4	57.1	54.7	45.1	42.8	67.6	64.1	312.2	309.7
8	58.3	62.4	143.4	152.6	100.7	101.0	21.4	18.0	86.6	87.1	410.4	421.1
10	152.7	166.5	110.0	123.7	125.2	122.2	44.4	40.2	47.7	44.1	480.0	505.7
12	41.8	47.3	180.7	188.5	50.8	58.6	15.8	14.6	18.3	17.0	316.4	326.0
14	107.8	117.8	83.9	84.1	65.2	63.7	3.4	5.0	23.6	21.1	283.9	291.7
Total	433.8	471.9	626.2	652.6	440.0	434.8	163.3	162.5	287.6	277.2	1950.9	1000.0

Winds less than 2 m/s: H, 27.5, B, 28.8.

A six months' comparison of the gauges side by side at the present site of the Beckley gauge gave 495 mm. for H and 501 mm. for B, or a ratio H/B for the gauges themselves, apart from exposure, of .98.

From Table II. it seems clear that the variation in the relative catches of the two gauges depends far more on wind direction than on speed. The first column (135°) is for a wind blowing

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from the hyetograph towards the Beckley gauge with the Observatory building as a more or less direct obstacle. The column headed 315° represents the opposite condition, and a comparison of these two sets of ratios shows that we have the same phenomenon in each case, but reversed with the wind direction. The gauge to leeward has the higher catch and the difference increases with the wind speed. The building, in spite of its distance from either gauge, acts as a fairly effective shield, but exactly how effective is not so clear. That the windward gauge will lose a larger proportion of the full rainfall as wind increases may be assumed with some certainty, but it may well be that the leeward gauge also loses more in the same circumstances. This means, of course, that if the leeward gauge were perfectly shielded, the ratios for 135° would be lower while those for 315° would be higher, supposing the present shielding to be less than perfect. We should also find a greater range as between the high velocity and low velocity ratios. The table as given, therefore, probably represents something less than the true variation in catch due to changing wind speed. Unfortunately the comparison for calms is not very reliable, but it will be noticed that the ratio obtained for the two gauges when side by side is the same as the mean ratio for the whole of Table II., so that probably no great error will be involved in taking .98 as the ratio for calms. This means that the building alone, in the winds considered, does, by its shielding effect, affect the catch certainly to the extent of 7 per cent., and probably more. This figure ignores all values in brackets, and also the low value .88 under 135°.

TABLE II.—Ratio H/B for Different Winds.

Speed m/s	SE (135°)	S (180°)	SW (225°)	W (270°)	N.W. (315°)	Totals.
3	(.92)	(.98)	.93	1.01	1.00	.97
6	.94	.98	1.04	1.05	1.05	1.01
8	.93	.94	1.00	(1.19)	1.00	.97
10	.92	.94	1.02	.90	1.08	.96
12	.88	.96	1.02	(1.08)	(1.08)	.97
14	.91	1.00	1.02	(.68)	(1.12)	.97
Mean	.92	.96	1.01	1.00	1.04	.98

Winds less than 2 m/s (.96).

As the wind goes round from South-east (135°) to North-west (315°) the effects of shielding become less apparent. For no direction away from the line of the gauges is there the same regular change of the ratio with speed, but the means for the different directions also show a gradual change from South-east (135°) to North-west (315°). At some direction between South (180°) and South-west (225°) the ratio assumes the value for no wind, so that hereabouts the effect on the gauges of the building is the same. It is evident, therefore, that the presence of the building is an important factor in determining the amount of rain caught.

The exposure of the Beckley gauge as regards distance from the building seems to rule out entirely the possibility of any loss

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which would be directly attributable to screening. The symmetry of the results in Table II. would seem to indicate, therefore, that the hyetograph site is similarly free from direct loss, although it is much less open than the site in the field. So far as these observations supply a test, therefore, it may be said that the standard laid down for the distances of obstacles by the Meteorological Office secures that the gauge shall be free from loss by direct screening.

It will be of interest to consider briefly the results obtained by a similar comparison of the catches of two gauges at different distances on the same side of the building. For this purpose we have available the records from the Dines gauge and the Beckley gauge, marked D and B on the plan. When these records are analysed in a manner similar to that adopted for the hyetograph and the Beckley gauge records discussed above, the results given in Tables III. and IV. are obtained.

TABLE III.—Analysis of Rainfall measured by the Dines Gauge (D) and the Beckley Gauge (B) according to Winds.

Speed.	SE (135°).		S (180°).		SW (225°).		W (270°).		NW (315°).		Totals.	
	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.
m./s.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
3	24.1	24.4	65.6	70.2	8.8	10.2	13.7	14.9	23.4	24.9	135.6	144.6
6	25.3	26.5	39.5	41.7	17.9	18.8	57.5	59.2	24.8	26.8	165.0	173.0
8	30.9	38.6	166.3	177.0	52.4	58.0	19.6	22.6	39.0	41.7	314.2	337.9
10	43.0	45.6	139.8	143.1	24.0	24.9	9.2	11.4	28.4	29.4	244.4	254.4
12	24.1	24.8	136.1	140.8	26.2	28.0	20.3	22.2	12.1	14.0	218.8	229.8
14	32.5	31.4	50.4	48.9	13.9	14.1	5.2	6.5	—	—	102.0	100.9
Total	185.9	181.3	597.7	621.7	143.2	154.0	125.5	136.8	127.7	136.8	1180.0	1240.6

Winds less than 2 m/s. : D, 59.2 ; B, 61.0.

TABLE IV.—Ratio D/B for Different Winds.

Speed m/s.	SE (135°).	S (180°).	SW (225°).	W (270°).	NW (315°).	Totals.
3	(.99)	.93	(.86)	(.92)	.94	.94
6	(.95)	.95	(.95)	.97	(.93)	.95
8	.96	.94	.90	(.87)	.94	.93
10	.94	.98	(.96)	(.81)	(.97)	.96
12	(.97)	.97	(.94)	(.91)	(.87)	.95
14	1.03	1.03	(.99)	(.80)	—	1.01
Mean ...	.97	.96	.93	.92	.94	.95

Winds less than 2 m/s : .97.

In this case the data utilised are confined to the period between the beginning of January, 1921, and the middle of February, 1922, as at this latter date the Nipher Shield was fitted to the Dines gauge and it is preferable to avoid any complication which may be introduced by this additional factor. The only shielding effect is, therefore, as before, any which may have been introduced by the building on the catch of either gauge, together with any which

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may have arisen from the natural slope of the ground, which, as previously mentioned, is of the order of 1 in 20 downwards to the North-west.

As before, it is found that changes in wind direction have a much greater effect on the ratio than changes in speed. The effects of varying speed appear to be somewhat irregular, but for most of the values in Table IV. the amounts of rain concerned are so small that no general conclusions can safely be drawn from the individual group values. Considering, however, the last column of means, the general tendency is undoubtedly for the ratio to increase with the wind speed, even though the actual figure 1.01 for 14 metres per second may be accepted with some reserve. The column headed 135° in this table represents a wind blowing from the building over the two gauges, and the other directions are best regarded as departures from this. The bulk of the rain falls with winds from the South (180°) and we find here unmistakable indications of the increase of the ratio with speed. It is inconceivable that the building should act as a better shield for the gauge at the greater distance and the only inference that can be made is that the additional influence of the slope of the ground comes into play. That this is probably the true explanation appears also from a consideration of the mean ratios for the different directions; for on the assumption that the Beckley gauge is gaining most from the protection of the building with a South-easterly wind, the loss of this protection should become evident in an increase of the Dines gauge catch relative to the Beckley gauge catch as the wind direction changes from the line of the building; that is to say, the ratio should increase, whereas the means for the different directions show that the opposite is the case, the explanation being that for a wind blowing across the slope, which happens to be the same as a wind blowing across the line of the building, the loss of the slope shelter at the Dines gauge is relatively greater than the loss of building shelter at the Beckley gauge.

From the results of these comparisons it appears that at a station where the greater part of the rain falls with wind from one direction, or from directions not covering a very wide angle, the closest approach to the true rainfall will be obtained if the rain-gauge, supposed, of course, to be exposed according to the standard specified by the Meteorological Office, is situated so that for these winds it is in the lee of a building or other similar obstacle and particularly if the ground has a slight slope downwards from the building towards the gauge. There is nothing in these experiments to indicate what would be the most desirable amount of slope, but as this is a factor which could hardly be under control, the omission is of no practical consequence. It is sufficient to say that any considerable amount of slope might introduce factors entirely different from those considered here; probably the slope of 1 in 20 of which we have experience in these observations is not very far short of the maximum permissible. These conclusions as to the effect of the slope of the ground have an additional interest as being to some extent illustrative of the principles involved in the pit method of shielding, which is discussed in a later section of the paper.

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II. The Nipher Shield.

The Nipher Shield as used at Valencia Observatory consists of an inverted hollow truncated cone fitted to the gauge as shown in Fig. 2. The upper edge of the cone in position is level with the rim of the raingauge. Probably the most effective investigation of the effect of this shield would be made by having two gauges, similar in all respects except for the shield, exposed on a perfectly level plain with no trees or buildings in the neighbourhood and with a considerable distance between the gauges in order to avoid any eddies due to the one having any effect on the other. Conditions such as these are not easily realised, especially at an observatory, and neither at Valencia nor anywhere in its vicinity could they be even approximately attained. Moreover, all the gauges in use at Valencia were fixed long before the present comparisons were undertaken, and in comparing any two of them it was necessary to recognise the extremely great probability that differences in their natural exposure would account for a considerable portion of any differences in their recorded rainfalls. There was the further difficulty that all these gauges were of different heights so that direct comparisons of their records were almost certain to raise more problems than they might solve. An indirect method of investigation was therefore adopted.

First, the falls recorded by the Dines gauge at D during the period when it was without a shield were computed as fractions of the corresponding falls registered by the Beckley gauge in the manner and with the results described in the previous section. Second, a like process was carried out with the records from these same gauges for the period during which the Dines gauge was protected by the Nipher Shield, the Beckley gauge remaining unshielded exactly as before. A comparison of the two sets of ratios should now be equivalent, theoretically, to comparing the records from a gauge with a shield with the records from the same gauge without a shield on exactly the same site. This method is not entirely free from objection, since it is impossible to select two periods sufficiently alike in the matters of wind and rates of rainfall to make the two comparisons with the Beckley gauge strictly parallel; but there seems to be no possibility, in the conditions obtaining at a station such as Valencia, of instituting any comparison which is likely to be as effective as one carried out on these lines.

The analysis of the records for the period without the shield has been given in Tables III. and IV. The corresponding analysis for the period with the shield in action, extending from February, 1922, to April, 1924, appears in Tables V. and VI. For the present discussion only the ratios are needed, but Table V. is given to complete the records.

A comparison of the mean ratios according to wind directions in Tables IV. and VI. gives the following results :—

Direction.	135°	180°	225°	270°	315°	Totals.
Shielded	.96	1.00	1.04	.96	.97	1.00
Unshielded	.97	.96	.93	.92	.94	.95
Effect of Shield per 100 mm.	−1	+4	+11	+4	+3	+5

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TABLE V.—Analysis of Rainfall measured by the Dines Gauge (shielded) and the Beckley Gauge according to Winds.

Speed	SE (135°).		S (180°).		SW (225°).		W (270°)		NW (315°).		Totals.	
	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.
m/s.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
3	47.7	49.9	60.1	60.2	44.0	43.1	36.5	36.3	39.2	38.9	227.5	228.4
6	60.9	62.8	138.4	139.5	89.0	88.0	45.5	47.1	70.8	73.4	404.6	410.8
8	99.7	102.7	158.2	160.6	90.7	87.7	60.4	63.0	77.7	82.7	486.7	496.7
10	48.9	52.1	231.9	226.8	102.9	97.6	54.1	57.4	60.0	62.4	497.8	496.3
12	52.0	53.4	243.4	232.8	76.9	71.5	13.7	15.7	34 2	33.6	420.2	407.0
14	41.6	43.9	140.7	139.1	43.1	42.5	6.1	7.0	33.2	34.0	264.7	266.5
Total	350.8	364.8	972.7	959.0	446.6	430.4	216.3	226.5	315.1	325.0	2301.5	2305.7

Winds below 2 m/s; D, 78.9, B, 78.9.

TABLE VI.— Ratio D/B for Different Winds (Dines' Gauge Shielded).

Speed m/s	SE (135°)	S (180°)	SW (225°	W (270°)	NW (315°)	Totals.
3	.96	1.00	1.02	1.01	1.01	.99
6	.97	.99	1.01	.97	.96	.99
8	.97	.99	1.03	.96	.94	.98
10	.94	1.02	1.05	.94	.96	1.00
12	.97	1.05	1.08	(.87)	1.02	1.03
14	.95	1.03	1.01	(.87)	.98	.99
Means	.96	1.00	1.04	.96	.97	1.00

Winds below 2 m/s, 1.00.

The variation of the shielding effect with wind direction is considerable and can only be interpreted as a measure of the variation with wind direction of the loss of rain when the gauge is not shielded. It appears, for example, that when the wind is blowing from the direction of the building (135°) the shelter given by the building itself, assisted by the slope of the ground, is not appreciably changed by the introduction of the shield; but for all other directions there is a decided improvement in the catch, amounting, in the case of the South-westerly wind, to more than a tenth of the total fall measured. If we may assume that the addition of the shield brings about something approaching uniformity in the percentage deficiency for different directions, it is perfectly clear that the direction at right angles to the line of the building is the direction of greatest loss with the unshielded gauge.

The variations of the ratios with wind speed, except for winds in the line of the building, cannot be deduced with any certainty from Tables IV. and VI. It seems probable that chance variations are sufficiently large to mask the real phenomena with the limited falls of rain available. In an attempt, therefore, to gain more certain information under this head these two tables have been recast into a new table, Table VII., in which the falls are given summarised as totals for wind speeds above and below 9 m.p.s. With such a large variation with direction, it is obviously desirable to maintain the division into separate sections for different directions.

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Reference need only be made to the ratios, the effect of the shield being the only phenomenon which is being investigated. It appears that with the gauge unshielded the ratio is greater for the higher wind speeds, an indication of a superiority in the matter of natural shelter of the site of the Dines gauge. This follows from the consideration that increasing wind can only affect the ratio of the catches of the two gauges by increasing their losses in unequal proportions. In the present case the higher wind, while it doubtless diminishes further the catch of the Dines gauge, diminishes in still greater proportion the catch of the Beckley gauge.

TABLE VII.

Speed.		SE (135°)		S (180°)		SW (225°)		W (270°)		NW (315°)		Total.	
	Gauge		D Shielded		D Shielded		D Shielded		D Shielded		D Shielded		D Shielded
m/s		mm.	m.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	m.	mm.	mm.
Below 9	D	86.3	208 3	271.4	356.7	79.1	223.7	90 8	142.4	87.2	187 7	614 8	1122.2
	B	89.5	215 4	288.9	360.3	87 0	218.8	06.7	146.4	93.4	195 0	655 5	1139.1
Above 9	D	99.6	142 5	326.3	616.0	64.1	222.9	34 7	73.9	40.5	127.4	565 2	1211.7
	B	101 8	149 4	332.8	508.7	67.0	211.7	40.1	80 1	43.4	130 0	585 1	1106 3
Below 9	Ratio D/B	.96	.97	.94	.99	.91	1.02	.94	.97	.93	.96	.94	.98
Above 9		.98	.95	.98	1.03	.96	1.05	(.87)	.92	.93	.98	.94	.99
Below 9	Percentage effect of Shield	+1		+5		+11		+3		+3		+4	
Above 9		−3		+5		+ 9		(+5)		+5		+5	

It seems natural to suppose that the addition of the shield would lead to the disparity between the ratios at low and high wind speeds being accentuated, since the shielding should go far towards eliminating the increased loss of the Dines gauge at high speeds, the Beckley gauge having, as before, no artificial protection; but reference to the figures for the shielded gauge in Table VII. shows that the increase in the ratio with wind speed is hardly any greater when the gauge is shielded than when it is not, and in some cases appears to be even less. This phenomenon supplies us with some valuable information as to the limits of the capabilities of the shield, since it can only mean that its effectiveness diminishes with increase of wind, the result being that as the wind rises the advantage of the shielded over the unshielded gauge becomes less. The proportion of the true rainfall caught by the shielded gauge, large at the lower speeds, becomes gradually smaller. This proportion nevertheless continues to be larger than that found in the unshielded gauge, but by a stationary or, it may be, decreasing margin. The result is seen in the last two lines of Table VII., where the difference between the ratios for the higher and lower speeds at each direction is shown as the percentage increase in catch produced by the shielding. There is no change with wind speed at all comparable with that due to alterations in direction, the mean for all directions showing a gain of 5 per cent.

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at high speeds and 4 per cent. at lower speeds. Although the compensating action of the Nipher Shield is thus seen to be imperfect, the results considered as a whole do indicate that by its use a considerable advance may be made towards making the readings of a raingauge represent the true rainfall.

III. Shielding in Pits.

Some years ago the suggestion was made by E. Gold that fresh observations should be made with a raingauge in a hollow in the ground, protection from high winds thus being afforded while the full rainfall should still be effective. This method of shielding would appear to have some very real advantages over the methods hitherto discussed, since in place of a shield to counteract the effects of eddies is substituted an arrangement in which the eddies are not formed in the first place, or at least are reduced to very small proportions. Observations with a gauge exposed in the manner suggested were commenced in February, 1922, at Valencia Observatory. The pit first used was of the form and dimensions shown in Fig. 3, the sides sloping inwards from the edge of the pit to a small flat space round the base of the gauge. The rim of the gauge was level with the surrounding ground and was a foot above the bottom of the pit. Observations were continued with the pit in this form for a year. For a year previous to the commencement of these observations the same gauge had been exposed on the same site with its rim one foot above the surrounding ground which continued unbroken up to the foot of the gauge. The comparison between the two exposures was made in the same manner as already described for the comparison of the Dines gauge with and without a Nipher Shield, but unfortunately with one important modification. The gauge used for the pit experiments was not a self-recording gauge and was read only at 9h. daily; consequently the rainfall could not be divided up according to the different wind velocities. In these circumstances the results obtained were divided into two sections, namely, one for the winter months October to March, and one for the summer months April to September, the former corresponding roughly to a high wind period and the latter to a low wind period.

Table VIII. gives the totals from the experimental pit gauge P and the Beckley gauge B for corresponding winter and summer periods. The upper half of the table gives information for the

TABLE VIII.—Shielding Effect of a Pit with Sloped Sides.

		Winter	Summer	Total
Normal Exposure.	Experimental Gauge P	857	417	1274 millimetres.
	Beckley Gauge B - -	831	416	1247 millimetres.
	Ratio P/B - - -	1.03	1.00	1.02
Pit Exposure.	Experimental Gauge -	704	639	1343 millimetres.
	Beckley Gauge - -	608	589	1197 millimetres.
	Ratio - - - -	1.16	1.08	1.12
Percentage Effect of Pit - -		+13	+8	+10

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interval during which the experimental gauge had a normal exposure, the lower half for that in which the experimental gauge was placed in the pit, together with a line showing the effect of the pit on the catch.

The protecting effect of the pit appears to be much greater than that of the shield. There is a phenomenon, however, which requires to be noted here. On several occasions after the fixing of the gauge in the pit, dirt, and in some cases even fine gravel, was found in the receiver. This might have come there through part of the catch having been in contact with the shingle round the gauge. Part of the extra catch may very well be due, therefore, to outside rain splashing into the gauge. There is no obvious means of estimating the magnitude of this addition to the catch.

In February, 1923, the pit was modified by the removal of the sloping sides, the gauge from that time on having the exposure illustrated in Fig. 4. The rim of the gauge was still level with the surrounding ground and the walls of the pit were vertical. It might reasonably be expected that the splashing into the gauge in this case would be much less than with the sloping pit, and as a matter of actual experience at no time since the modification was effected was any dirt or gravel found in the receiver.

The results given in Table IX. are from the gauge with the pit modified as described. They extend from February, 1923, to April, 1924, and are shown in a form similar to those in Table VIII., from which table the ratios for the gauge exposed normally are taken.

TABLE IX.—Shielding Effect of a Pit with Vertical Sides.

		Winter	Summer	Totals
Normal Exposure	Ratio P/B - - -	1.03	1.00	1.02
Pit Exposure	Experimental Gauge P	2225	1316	3581 millimetres.
	Beckley Gauge B - -	1971	1230	3210 millimetres.
	Ratio P/B - - -	1.13	1.10	1.12
Percentage Effect of Pit - -		+ 10	+ 10	+ 10

These figures indicate that if, according to expectation, splashing is eliminated or greatly reduced, the shielding action of this pit must be correspondingly greater than that of the sloped pit, or else that the effect of splashing is negligible in either pit. The shielding with either type of pit seems to result in an increase on the average of about a tenth in the catch.

The general inference to be drawn from these experiments is that the pit in one form or another, preferably the vertical-sided type, is the most efficient of the methods of shielding considered in this investigation. Eliminating wind eddies gives better results than counteracting them, as was anticipated, the proportional improvement in the measured rainfall with a pit being about twice that obtained with the Nipher Shield.

It seems probable that with this last form of protection we are making a very near approach to the true rainfall. It is fitting,

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therefore, assuming that the true rainfall is by this means actually attained, to conclude this paper with a list giving the proportions of the total rainfall which may be supposed to be caught by each of the gauges in use at Valencia. The respective exposures may be judged from what has already been said in the introduction to the paper.

	%
8in. gauge in pit	100
8in. gauge normal exposure	90
Beckley gauge	89
Dines gauge normal exposure	84
Dines gauge with shield	90
Hyetograph near site of Beckley gauge ...	84
Hyetograph behind house	93

I wish to express my thanks to Lt.-Col. E. Gold, who suggested this extremely interesting investigation; to Mr. L. H. G. Dines, to whose initiative I owe it that I found the pit and the Nipher Shield already in action when I first came to Valencia, and to the Director of the Meteorological Office, Air Ministry, by whose permission this paper is published.

Note added November 13, 1925.

Since this paper was written an account has appeared in the *Meteorologische Zeitschrift* (July, 1925) of a series of observations on the effect of the Nipher Shield by A. Röstad at the Haldde Observatory in Norway. The observations extend over twenty months and the major portion of the data afforded is for precipitation in the form of snow. The effect of wind is so much greater on snow than on rain that no comparison is possible between Röstad's results as a whole and those obtained at Valencia, but his figures for rain alone indicate an average improvement in catch due to shielding of 6.5 per cent., as compared with the average improvement of 5 per cent. found at Valencia. The difference is not greater than may reasonably be supposed to arise from differences in local conditions such as the slope of the ground.

It is of interest to examine these results for evidence of the decreased effectiveness of the shield for high winds which the Valencia results seemed to indicate. For rain alone no very definite conclusion can be arrived at one way or the other. For wind speeds of 3, 6 and 9 metres per second the percentage increases in catch are 4.9, 7.4 and 7.5. As far as they go, these results appear to show the same effect as was observed in the Valencia figures, but the last-mentioned percentage, 7.5, is for a rainfall of only 14 mm. and is to some extent, therefore, doubtful. For various snowfall groups the following percentage increases in catch are found :—

	3 m/s.	6 m/s.	9 m/s.	14 m/s.	19 m/s.
1.	40	81	55		
2.	47	71	145	141	95
3.	41	76	113	140	96

The results are quoted in each group only so far as reasonably large quantities of precipitation are concerned. In each case a speed does appear to be reached beyond which there is a reduction in the proportion of the catch which is due to shielding, but for all groups such speed is much higher than the corresponding speed in the Valencia observations, even more so, in fact, than at first

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appears, since these speeds are all reduced to raingauge level, whereas at Valencia the speeds quoted are, of necessity, anemometer speeds, that is, at a height of 40 feet.

DISCUSSION.

Dr. H. R. MILL writes: I have read Mr. Stewart's paper with much interest and recognise the value of such detailed observations on numerous rain gauges in a situation where the exposure differs only slightly. As a rule the comparisons of rain gauges in wind have been made under conditions of great disparity, as in the numerous series recorded in *British Rainfall* at frequent intervals during the last half century. I regret that these earlier experiments at Colne, Strathfield, Turgiss, Hawsker, Rotherham and elsewhere, were not referred to in the paper, as they would have suggested many points for comparisons with the Valencia results. To anyone desirous of formulating rules for the correction of rainfall records to any assumed normal exposure, I should urge a careful study of the numerous researches made in this country and abroad. It would take up too much space here to cite all the references, but many of them are given in my article "The development of rainfall measurement in the past forty years," in *British Rainfall*, 1900, p. 23, and in Mr. Bonacina's article on "The effects of exposure to the wind upon the amount of rain caught by rain gauges and the methods of protecting rain gauges from them," in *British Rainfall* 1906, p. 27.

My personal feeling is that in order to obtain results of the highest value with regard to protection against wind disturbance, we ought not to rely on comparisons between gauges of different patterns and at different heights above the ground, although I realise that this may be less liable to mislead in the conditions described by Mr. Stewart than it would be if the gauges were in a mountainous district. However, I should be inclined to accept as the last word on the subject only results obtained from the simultaneous observations of rain gauges identical in pattern, material and height above ground, and varying only in the degree of shelter from wind. My experience has not been that so great a difference of catch as Mr. Stewart finds is to be expected in ordinary conditions of observing when total amounts for a year or series of years are compared, and I suggest that the series of observations be continued with gauges of one pattern and height.

Dr. J. GLASSPOOLE in a written communication expressed his interest in the paper as it was concerned with the question of the exposure of rain gauges. He had gained some information on the subject by the inspection of some hundreds of rain gauges on behalf of the Meteorological Office, and by comparing the values, from gauges with differing exposures, on large scale maps of the average annual rainfall. This was the method which had been utilised by Dr. H. R. Mill and the late Mr. Carle Salter with such success. Mr. Stewart was at a great disadvantage in not having records in the neighbourhood with which to construct a map and to compare his results.

The selection of a good exposure in a windy position necessitates the provision of some shelter, either natural or artificial. In further support of this, reference may be made to the type of exposure common in towns, where very reliable records are made and where each gauge has clearly a very material amount of shelter. In order to bring these two types of exposures—that on moors and that in towns—into accord there seems ample justification for the provision of some shelter in the former instance. A further confirmation that the values from these sheltered gauges are more reliable than those from unsheltered gauges has been obtained in

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certain cases by measurements of the actual stream flow from the areas in question.

While most of these generalisations have been arrived at by the study of rain gauges exposed on moorlands, there is a close analogy with the conditions prevailing at Valencia. There the land in general slopes up from the sea in the direction of the prevailing wind, which has an almost unbroken run across the Atlantic. It is also noticeable that in the paper the gauge at B recorded less than that at H with north-west winds, *i.e.*, with winds blowing up a slope to the gauge. Further, the gauge at H, which has most shelter in the direction of the prevailing winds, recorded a fall most nearly equal to that measured by the gauge in the pit.

There is no doubt that good exposures on moorlands are often obtained when the gauge is in a slight hollow. He (Dr. Glasspoole) was particularly impressed with the exposure of one gauge he saw in Central Wales in September last, where the gauge was in a natural hollow, a close approach to the type of exposure in a pit that Mr. Stewart had used. The diameter of the hollow in this case was about 10 yards and the depth 1ft. to 1ft. 6in. The values from this gauge were concordant with those from surrounding gauges. It would be extremely instructive if Mr. Stewart would place a standard M.O. gauge in a position at Valencia with adequate shelter all around, especially in the direction of the prevailing wind. It seems probable that values so obtained would be even more in agreement with those given by the pit gauge. If this fact could be established, some advance might be made towards the standardisation of rain gauge exposures by the introduction of the method of shielding gauges by placing them in a pit of suitable dimensions, instead of providing some shelter, either by moving the gauge so that it is sheltered by the rise of the ground, or by the erection of a turf-wall—methods which have met with success in other localities.

Mr. R. CORLESS in a written communication stated :—

Our thanks are due to Mr. Stewart for this analysis of rain gauge exposures according to the strength and direction of the wind.

Such a method can only be used at stations with self-recording anemometers and self-recording rain gauges. Observers who are situated in exposed places and are in a position to do so, could help very materially in the study of rain gauge exposures if they would carry out experiments on lines similar to those of Mr. Stewart.

It should perhaps be emphasised that the evil influence of wind upon the catch in a rain gauge depends not at all upon the fact that the drops of rain fall obliquely, but merely upon the fact that eddies are produced in the neighbourhood of the gauge which prevent the drops from continuing their normally oblique but straight paths into the mouth of the gauge. Thus one is led to an analysis of rain gauge exposures according to (a) site, and (b) exposure of gauge on the site. A site on the top of a bank or ridge of a roof does not receive rain, which is representative of the locality, because of the influence of the bank or roof itself in disturbing the streamlines of air; hence it would be useless exposing a rain gauge on such a site, no matter how protected the gauge itself might be by Nipher shield or pit or other contrivance. On the other hand a site on a treeless windswept plain would be satisfactory *as a site*, but great precautions would be needed in exposing the gauge to shield it so as to minimise the disturbing eddies caused by the gauge itself—clearly the ideal arrangement is if possible to secure a site which is representative of the locality as regards rainfall, but is reasonably free from strong winds. A courtyard surrounded by high buildings, such as that at the Victoria and Albert Museum, does

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not conform with the usual rule that the distance of objects should be not less than twice their height: yet it forms a perfectly satisfactory site for a rain gauge and no special precautions in exposure are needed: on the other hand the treeless plain conforms with the rule, but special precautions are in this case needed in exposing the gauge.

Dr. Wild, of Russia, recommended the use of a wooden enclosure 16ft. square and 8ft. high surrounding the gauge. This forms a miniature courtyard and is more effective than a Nipher shield. It would be interesting to ascertain whether the enclosure could be still further reduced in area and height without detriment to the result.

Mr. STEWART, in reply, said that while he recognised the additional value which his experiments would have had could he have compared his results with those of previous workers, as rightly urged by Dr. Mill, he had of necessity to leave his work to that extent incomplete owing to his having neither the time nor the facilities for collecting the data from other sources; and his results were never regarded by him as being anything more than an addition to what had already been done, and not in any way as a "last word" on the subject. He fully accepted also Dr. Mill's contention that really satisfactory comparisons demand rain gauges identical in pattern and height above the ground; and, in fact, he attempted to avoid any complications due to the lack of uniformity among the gauges at Valencia by treating the records in a special manner. He thought that Dr. Mill's criticism on this ground applied only to that section of his paper which deals with the shelter afforded by buildings and to the table given in the last paragraph; but in the first case he laid stress, not on the actual figures obtained, but only on the way in which the ratios vary with the wind. The last paragraph is given only as a rather striking illustration of how largely the catch can depend on conditions of exposure, exposure including height, diameter and site. The actual comparisons in the cases of the Nipher shield and the pits are not between different gauges as the difficulties inseparable from such comparisons were recognised from the first; the method of ratios was devised expressly to avoid these difficulties and to secure that the comparisons should be as nearly as possible between catches from the same gauge in different conditions of exposure with respect to wind only. In the circumstances in which this work was of necessity carried out he doubted whether any more effective method was available.

In regard to Dr. Glasspoole's contribution, he thought that the object desired by a rainfall organisation was hardly the same as that which was in his mind with regard to the Valencia experiments. The securing of uniformity of exposure for cartographical purposes and the accurate measurement at one particular station are in reality two quite distinct problems. For the cartographer uniformity is more important than absolute accuracy; lack of uniformity appears on the map and can, in most cases, be rectified by suitable modifications in site or exposure, but it would be too much to claim that absolute accuracy at each station is thereby secured. At an individual station, such as Valencia, on the other hand, an accurate knowledge of rainfall on the site may be desired for quite different objects, for example, the effective correction of evaporimeter records for which even the most perfect concordance with district map values would not by itself be sufficient guarantee of accuracy. He thought it was not improbable that any individual observer who could by some means secure absolutely exact measurements of rainfall, would find that the totals would show serious differences from the isohyetals for his district.

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ON CORRELATION COEFFICIENTS, THEIR CALCULATION AND USE.*

By Sir GILBERT WALKER, C.S.I., F.R.S., and E. W. BLISS, M.A.

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INTRODUCTION.

If we are seeking the nature of the relation between two factors, perhaps vaccination and smallpox mortality, or unemployment and investment in national funds, or pressure and rainfall, it is obvious that, if we plot curves showing the successive values of the two factors, we shall obtain a better idea with less effort than if we merely look at the tables of the successive values. We are as well off as an individual with a perfect memory. But there are many situations in which the comparison of graphs does not lead to a definite conclusion; there may be doubt whether there is any relation of cause and effect, or if there are three or more variables all related it may be impossible to disentangle the direct from the indirect relations; the similarity of the variations of A and B may be due to the control of each of these by C. We are thus driven a stage further in our economy of brain effort through mechanical agency, and we employ the methods of statistics, working out correlation coefficients and regression equations; and we are then in possession of results which could otherwise be obtained only with considerable effort by an individual with first-rate insight and reasoning power, as well as a perfect memory.

It must be admitted, however, that statistical methods have not been adopted as generally as they deserve, and the reason is, I think, twofold. Firstly, the amount of arithmetic involved is considerable, and many meteorologists will spend an hour on a coefficient, though a few individuals may calculate one in 15 or 20 minutes; and secondly, the results are often not convincing, for some workers are continually finding small coefficients indicating relationships which break down as soon as they are applied to forecasting. We need a much more complete system of criteria, not only of the reality of our relationships, but also of their yielding a reliable forecast on any given occasion: as we shall see later under some circumstances a factor with a moderate degree of relationship may provide a forecast with a better expectation of success than another factor with a higher degree of relationship under less favourable circumstances.

Another matter requiring examination is the widely prevalent habit of correlating changes (*i.e.*, differences between successive values) of a series instead of departures from the mean value. Similarity of changes, as between PQR and pqr in Fig. 1, produces parallelism of the graphs of successive values, though the departures may be in reality opposite in character, as will be seen from the figure; and if this method be accepted without safeguards the paradox follows[1] that any series of figures, haphazard or actual, can be forecasted with a correlation coefficient of .5. Thus in Fig. 1 the

* See note in reference to this paper on p. 126.

[1] This is established in § 5 below.

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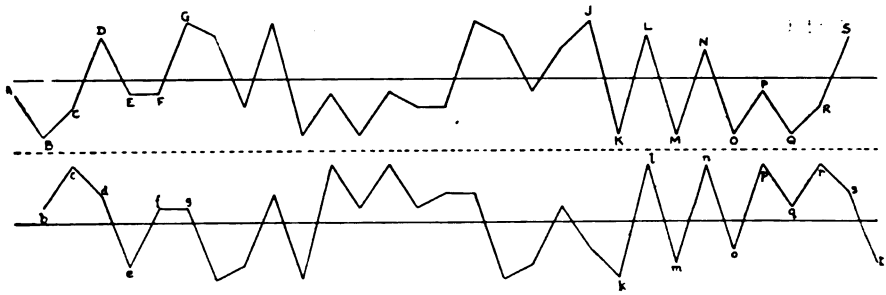

FIG. 1.

upper curve indicates an entirely fortuitous series of integers ranging from 1 to 9, and the lower curve is obtained by reversing the upper one (*i.e.*, measuring downwards instead of upwards) and shifting it on one step; the departure of any point k in the lower curve is the departure of the previous point J of the upper curve measured in the opposite direction, and is available as a forecast for K which would in spite of appearances prove worthless in the long run.

SECTION I.

If a meteorologist has about 45 years of annual data the probable error of a correlation coefficient not exceeding .5 will be about .1, and it is useless for him to work out its value to accuracy greater than .01. Further, he is habitually tempted by the mere scantiness of his materials to employ them in the full detail in which they are obtained. But if the variable is a departure of monthly pressure and its standard departure in thousandths of an inch is 20, the question naturally arises whether these numbers can, without loss of final accuracy, be divided by such a number as 2, or even 4; the new unit would be .002 or .004, and the nearest integral number of units would be taken. The reply, given by theory and practice alike, is that we can by division reduce the standard deviation (S.D.) to four units without introducing a significant error.[2]

If in the case just considered, with data correct to .001 we divide by 4 we reckon all values of a departure x between $\pm.002$ as if x were 0, all between .002 and .006 as if x were .004, and so on. In other words, we form groups separated by limits at $\pm.002$, $\pm.006$, $\pm.010$, $\pm.014$, etc., and reckon all x's within a group as if they had the central value of the group within which they lie. We have then to determine the error involved in replacing the true values of x and y in $\Sigma xy/s_1 s_2$ by the central values of the groups within which these values lie. We shall begin with the error in r due to error in the numerator, assuming for the moment that the denominator is worked out accurately. Distinguishing the approximate group-values by dashes we may call $x'-x=p$, $y'-y=q$,

[2] In published statistical computations of weather data there are in general no preliminary reductions in the magnitude of departures to save labour; but in the useful *Computer's Handbook*, Section V., p. 18 (1915), W. H. Dines recommends dividing by 3 if the departures range up to 100 or so or by 10 if they range to 300. This means working with a S.D. of about 12, and in his example the S.D.'s are 18 and 16 times the unit.

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where p, q, lie between $\pm c/2$, c being the width of the group, or group-interval. Also

$$\Sigma x'y' = \Sigma xy + \Sigma py + \Sigma qx + \Sigma pq,$$

and, as a first approximation, we may ignore the fact that the frequency distribution of p and q does not obey the ordinary law; thus dividing by n, the number of terms,

$$rs_1s_2 = rs_1s_2 + r_1s_3s_2 + r_2s_1s_3 + r_3{s_3}^2$$

where r_1, r_2, r_3 are the correlation coefficients between p and y, q and x, and p and q; and s_2, the standard deviation of p or q, is $c/12^{\frac{1}{2}}$.[3]

Now calculation from the error curve shows that even when c is as large as $s_1/4$ the true correlation coefficient (*i.e.*, the mean of a very large number of actual coefficients) between p and x is less than .00001, so that however closely x and y may be related the true values of r_1 and r_2 will be negligible; thus, as the data available are limited in quantities, the values of r_1 and r_2 actually found in practice will differ from zero by quantities obeying the error law, and will have probable values of $.67n^{-\frac{1}{2}}$ where n is the number of terms.

Accordingly in

$$r' - r = r_1s_3/s_1 + r_2s_3/s_2 + r_3{s_3}^2/s_1s_2$$

we note that if s_1 and s_2 are not smaller than $4c$, the ratio $({s_3}^2/s_1s_2)^{\frac{1}{2}}$ will not be greater than $1/8\sqrt{3}$; and it will generally be less.

So we neglect the third term by comparison with the first two, and the mean value of $r' - r$ will be $.67\ n^{-\frac{1}{2}}\ ({s_3}^2/{s_1}^2 + {s_3}^2/{s_2}^2)^{\frac{1}{2}}$.[4]

Now if the S.D.'s of our series are four units, *i.e.*, if s_1 and s_2 are four times c, $({s_3}^2/{s_1}^2 + {s_3}^2/{s_2}^2)^{\frac{1}{2}}$ is .1, approximately. Thus, while the error in r due to shortness of data is $.67\ (1 - r^2)/n^{\frac{1}{2}}$ or $.67n^{-\frac{1}{2}}$ when r is small, that introduced by grouping is about a tenth of this amount and may therefore be neglected.

The errors in the standard deviations may now be considered. Instead of s_1 we have s'_1 where

$${s'_1}^2 = n^{-1}\Sigma\ (x + p)^2 = {s_1}^2 + 2r_4s_1s_3 + {s_3}^2$$

where r_4 is the correlation coefficient between x and p; and the average value of r_4 being in general small its actual value will usually differ from its small average value by an amount obeying the error law, with a probable value of $.67\ n^{-\frac{1}{2}}$. The numerical value of the second term is, if $n = 40$ and $c = s_1/4$, $.0165\ {s_1}^2$, while that of ${s_3}^2$ (Sheppard's correction) is $.005\ {s_1}^2$, leading to a correction in s_1 of $.0026\ s_1$. Thus the chief error in s_1 is that due to the second term and has a probable value of $.008\ s_1$, which is .07 of that due to shortness of data. When this theory was applied to 20 cases as a test the agreement was satisfactory, the probable error found being .007 against a calculated amount of .006.

The error introduced into $\Sigma xy/s_1s_2$ due to both s_1 and s_2 is $.07 \times 2^{\frac{1}{2}}$, or .1, of the inevitable error due to shortness of data; and if we include the .1 from the numerator we shall have .14 or 1/7

[3] If the group limits of y were different from those of x we should multiply y by a constant factor so as to get the same limits.

[4] *cf.* Yule's Introduction to the Theory of Statistics, Chapter XI., § 2.

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of that due to $.67\,n^{-\frac{1}{2}}$. If a few isolated coefficients are needed this may be accurate enough; but when each factor has to be correlated with twenty or more other factors it is usually worth while to work out the S.D.'s to a higher degree of accuracy; for the time spent on the S.D.'s of 21 (or more) factors provides material affecting 210 coefficients, so that it is economical to work out the denominators of the coefficients to a higher degree of accuracy than the numerators.

Section II.

These conclusions are in accordance with the practice of statisticians when handling several thousands of cases; the data are arranged in a table of double entry and 25×25 compartments are usually regarded as adequate. Now a range from -12 to $+12$ units is associated with a S.D. of about 4; the main source of error due to replacing accurate meteorological data by the central value of the group into which they are placed is proportional to $n^{-\frac{1}{2}}$; and so it will bear the same ratio to the probable error of the correlation coefficient when n is small as when it is large. So the justification for arranging in 25 groups is about as great with 40 data as with 4,000.

The effect in practice of a S.D. of 4 or 5 is that all products are known without wasted effort and the process of addition on a comptometer or other adding machine is easy and rapid.[5] When the departures of the variables have been tabulated and the S.D.'s have been determined with sufficient accuracy (using Sheppard's correction if thought fit), the determination of a correlation coefficient with 40 pairs of values should not occupy on an average more than four minutes according to the skill of the operator.

Section III.

When applying statistical methods to forecasting, a knowledge of the degree of reliability is essential; and we shall examine the frequency with which a forecast made with a given correlation coefficient will indicate a departure of the correct sign. It is true that a minute excess and a minute defect should each be classed as "normal," but as there is no general agreement upon the limits of the "normal" group, or as to the method of scoring successes if this grouping is adopted, it will suffice for the present to consider the simpler problem. If we are forecasting a departure x with S.D. s_1 on the basis of the departure y of another variable (or group of variables), with S.D. s_2, then the forecast (OA in Fig. 2) corresponding to y is $ry\,s_1/s_2$ and its standard error is ks_1, where $k^2 = 1 - r^2$. If then we draw the error curve of S.D. ks_1 which has a vertical line through A as its axis of symmetry the chance of a right sign is the ratio of the area $XOCBX'$ to the total area of this error curve; for the likelihood of occurrence of a departure OP is proportional to the ordinate PQ. This ratio can be derived from

[5] If the number of columns on the comptometer is $2m$ it is a useful plan to assign the m to the right and the m to the left to positive and negative products, so that no subtraction need be done until the positive and negative totals have been read off. When much use is to be made of data it may be worth while to reduce the departures by means of a slide rule so that the S.D.'s are all $\sqrt{20}$; when Σxy has been found $s_1 s_2$ will be 20 and calculation is reduced.

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Table I. or II. of Pearson's *Tables for Statisticians*, and the probability must be integrated for a series of values of y over its distribution curve.[5] The table of probability p for various values of r is:

r	.0	.05	.1	.15	.2	.25	.3	.35	.4	.45	
p	.500	.516	.532	.548	.564	.581	.597	.614	.631	.649	
r	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
p	.667	.686	.705	.725	.747	.770	.795	.823	.856	.899	1.000

The agreement with experience is satisfactory as will be seen from Fig. 3 giving 57 actual results. It will be noticed that we

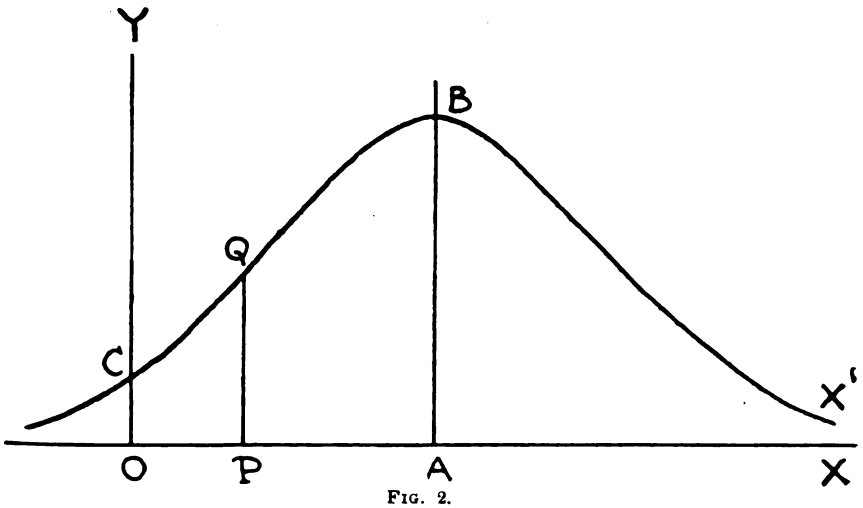

FIG. 2.

cannot expect to have four signs out of five correct unless r is as great as .8.

SECTION IV.

Experience very soon teaches one who applies statistical methods to forecasting that when his data indicate a decidedly abnormal season they are not likely to mislead, but if the conditions are only slightly abnormal an anticipation based on them has little value. Also when trying to build up confidence it is better to restrict the number of forecasts rather than issue them at times when the risk of failure is considerable. If, for example, r has the small value of .6, a prediction made on every occasion will, as the previous section shows, be correct in only 70% of them as compared with 50% due to tossing a coin: but, as we shall see shortly, there are 26% of occasions when conditions are sufficiently marked to give a

[6] Thus if $r=.6$, $k=.8$ and if the departure of y is $\frac{1}{2}s_2$ the forecast corresponding to it is $.35^1$. Thus in Table II. we find that for an abscissa of $3/8$ the value of $\frac{1}{2}(1+\alpha)$ is .646. This is the likelihood that the forecast will be correct in sign when y is $\frac{1}{2}s_2$; and in order to find the total likelihood for all values of y we note that in Table II. corresponding to an abscissa $\frac{1}{2}$ the ordinate z is .352; then we form products $.646\times.352\times$ the interval between successive values of y; and the result obtained by summing the products for all the intervals is the probability that the forecast on any occasion selected at random will have the correct sign.

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4 : 1 chance of success. I hold that with such a value of r temerity is definitely to be discouraged.

If r is .75 an anticipation with a 4 : 1 chance of success can be made in 46%—roughly a half—of the years: and in most of the 46% of years the indicated departures will materially exceed the inferior limit with which the reliability of 4 : 1 is associated.

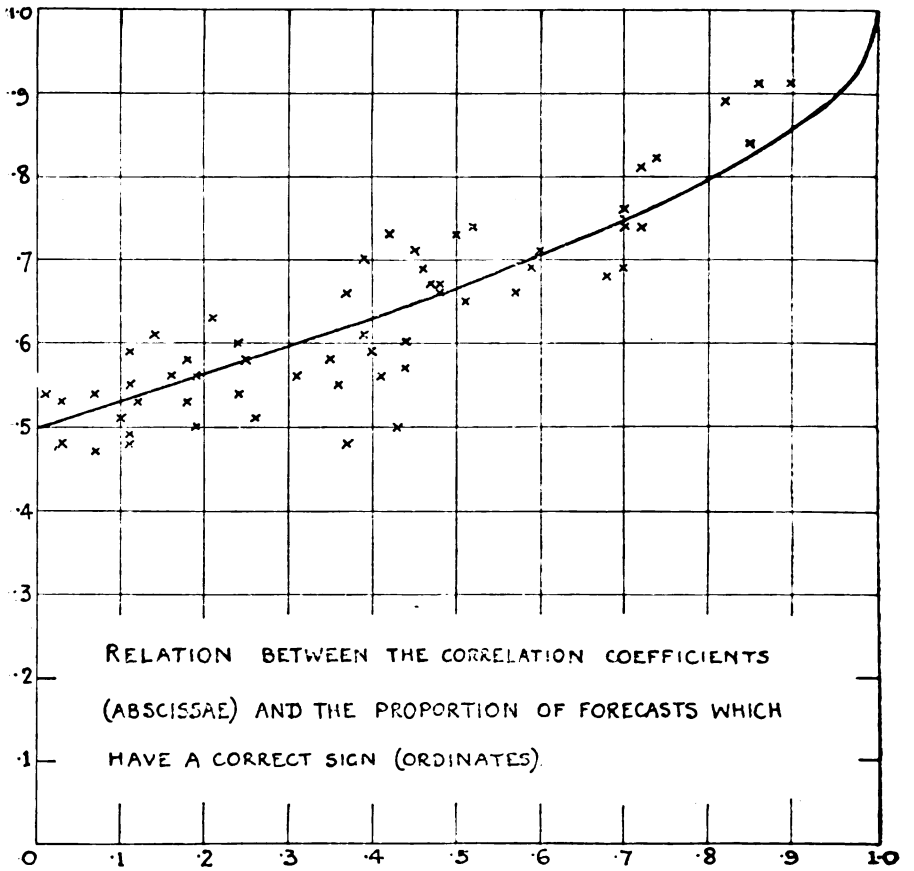

FIG. 3.

As in the previous section corresponding to a departure of y of the controlling factor (or factors) the forecasted departure will be $ry\,s_1/s_2$ and its standard deviation ks_1 where $k^2=1-r^2$. We must now have an area $XOCBX'$ forming 4/5 of the total area and in Sheppard's table corresponding to $\frac{1}{2}(1+\alpha)=.8$ we find an abscissa of .842; so when the standard deviation is ks_1 the departure of the forecasting factor must be given by $ry\,s_1/s_2=.842\,ks_1$; and in order that the probability of success may be at least .8, the value of y/s_2 must not be less than $.842\,k/r$. The probability of y exceeding this is $1-\alpha$ in Sheppard's notation and may be derived from Pearson's Table II. The probability that with values 0, .1, .2, ...9, 1.0 of r it will be possible to make a forecast with a 4 : 1 likelihood of

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correctness is given in the table below (Table I.) in the last column. A forecast is justified when the forecasted departure is greater than $.842\ ks_1$ (or rs_1 multiplied by $.842\ k/r$ in the third column); and when the forecasted departure is less than this a forecast is not justified.

TABLE I.—GIVING PROBABILITY THAT WITH GIVEN VALUES OF r IT WILL BE POSSIBLE TO MAKE A FORECAST WITH A 4 TO 1 CHANCE OF CORRECTNESS.

r	k	$.842\ k/r$	$1-a$
0	1	∞	0
.05	.999	16.8	0
.1	.995	8.38	0
.15	.989	5.53	0
.2	.980	4.13	.00004
.25	.968	3.26	.0011
.3	.954	2.68	.0074
.35	.937	2.25	.024
.4	.917	1.93	.054
.45	.893	1.671	.094
.5	.866	1.458	.14
.55	.835	1.278	.20
.6	.800	1.123	.26
.65	.760	.9845	.32
.7	.714	.8589	.39
.75	.661	.7421	.46
.8	.600	.6315	.53
.85	.527	.5220	.60
.9	.436	.4077	.68
.95	.312	.2766	.78
1	0	0	1

The effect of insistence on a higher reliability than that associated with a probability of 4 : 1 is a matter of some interest, and the following table (Table II.) in which the critical probability is 5 : 1 may be compared with the previous one.

TABLE II.—GIVING PROBABILITY THAT WITH GIVEN VALUES OF r IT WILL BE POSSIBLE TO MAKE A FORECAST WITH A 5 TO 1 CHANCE OF CORRECTNESS.

r	$.967\ k/r.$	$1-a$
0	∞	0
.1	9.62	0
.2	4.74	0
.3	3.08	.002
.4	2.22	.026
.5	1.67	.095
.6	1.29	.197
.7	.986	.324
.8	.725	.468
.9	.468	.640
1.0	0	1.0

The consequence of the increase of severity is material; in order to justify a forecast on half the possible occasions the value of r must be .82, whereas with a 4 : 1 chance it was .78.

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Section V.

It now remains to consider the result of tabulating correlation coefficients with changes in the variables (*i.e.*, differences between successive values) instead of departures from the normal. This method has been largely employed by Okada in Japan and by various writers in America in order to avoid effects due to secular change; but as we shall see, the changes of two series of variables may be connected while the departures are unconnected, and hence the method appears unjustified unless special precautions are taken. If this statement is not accepted and if two series are regarded as related when their changes are related it follows that any series of random figures may be forecasted with a correlation coefficient of .5. If this original series has random departures

$$u_1,\ u_2,\ u_3 \ldots u_{n-1},\ u_n$$

all that we have to do is to consider the relation of the two series

$$u_2,\ u_3,\ u_4 \ldots u_{n-2},\ u_{n-1},\ u_n$$

and

$$-u_1,\ -u_2,\ -u_3 \ldots -u_{n-3},\ -u_{n-2},\ -u_{n-1}$$

The series of their changes are

$$u_2-u_2,\ u_4-u_3,\ \ldots u_{n-1}-u_{n-2},\ u_n-u_{n-1}$$

and

$$u_1-u_2,\ u_2-u_3 \ldots u_{n-3}-u_{n-2},\ u_{n-2}-u_{n-1}$$

It follows that when n is large, the correlation coefficient between these two series of changes, the u's being independent, is $\Sigma u^2/2\Sigma u^2$ or $\frac{1}{2}$.

If we consider the changes of two series $x_1,\ x_2 \ldots x_n$ and $y_1,\ y_2 \ldots y_n$ we find for the correlation coefficient the value

$$\sum_{p-1}^{n} (x_p-x_{p-1})(y_p-y_{p-1}) / \{ \Sigma (x_p-x_{p-1})^2 \Sigma (y_p-y_{p-1})^2 \}^{\frac{1}{2}}$$

and if $\Sigma x_{p-1}\ y_p=0$, and $\Sigma x_p\ y_{p-1}=0$, as well as $\Sigma x_{p-1}\ x_p=0$, and $\Sigma y_{p-1}\ y_p=0$, it may be verified that this gives $\Sigma xy/(\Sigma x^2\ \Sigma y^2)^{\frac{1}{2}}$ the correlation coefficient of the original series. Unless the four conditions just mentioned (or their equivalents) have been examined it is not legitimate to derive conclusions from the relationships between the changes of the series.

Summary.

The present paper contains:—

(*a*) An account of a method of effecting a considerable reduction in the labour expended in working out correlation coefficients;

(*b*) Calculations (i.) of the likelihood that with a given coefficient r the forecasted and the actual departures will have the same sign, and (ii.) of the frequency with which, r being given, it will be possible to make a forecast with a 4:1 chance in its favour; and

(*c*) An account of ill effect of working with differences instead of departures unless special precautions are taken.

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DISCUSSION.

Mr. R. H. Hooker thought that the Society was much indebted to Sir Gilbert Walker for this paper and his examples of the high coefficients that could be obtained from haphazard observations were very useful. As an analogous illustration, he would like to call attention to the successes that might be obtained from forecasts based on pure chance. In a country, such as this, where the rain-days numbered about 180, anyone forecasting rain on 180 days at hazard throughout the year would be right in 50 per cent. of his cases; and if a forecast were regarded as correct when the rain fell on an adjoining day, the percentage of "correct" forecasts would be far higher: he (Mr. Hooker) would not be surprised to hear that such chance forecasts might be correct eight times or more out of ten. He had listened on the previous day to an extraordinarily interesting address at the Statistical Society by Mr. Udny Yule, who took as his subject much the same problem as Sir Gilbert Walker had taken, and he hoped that he and Sir Gilbert Walker might collaborate in the investigation of this subject. With regard to the correlation of successive differences, Sir Gilbert Walker very properly pointed out that they wanted to be used with great caution. He had used such coefficients himself, and he would like to point out a case where they were extremely useful, although it was not connected with weather statistics. He was correlating prices of wheat, the question being how far the price at one town depended on that at another. He had found in the middle of the period that the price of the variety selected at the one town was no longer quoted, but was replaced by another of a closely similar grade, the quotations of which overlapped the other for a short period. Now, of course, he could not switch from the average of the first to the average of the second, but by using successive differences he could switch from one grade to the other and get an almost complete set of observations. Correlation of successive observations thus sometimes allowed of a coefficient being obtained when it was impossible to calculate the usual coefficient.

Mr. C. E. P. Brooks remarked that he was glad to have heard Sir Gilbert Walker's paper, because he was in the throes of a great amount of correlation work. He thought that Sir Gilbert Walker had rather exaggerated the time required for computing a coefficient by the usual methods; some of the computers in the Meteorological Office took an average time of about five minutes. But at the same time, he was glad to have particulars of Sir Gilbert's method of using the standard deviation as a unit, and proposed to adopt it in future. He also wanted to speak about the question of using the change from year to year as a variant, because a very interesting instance had come to light where there was a correlation between two variants, one of which had a secular variation and the other had not. The regression equation of the form $x = a + by$, worked out in the ordinary way, gave values for the latter element which were below normal for all the later years, instead of fluctuating about the normal as they should have done. This led to persistent errors in experimental forecasts, and he was now trying to avoid these errors by correlating changes from one year to the next instead of the deviations from the mean.

Dr. Chree said that so much apparently unnecessary correlation work went on, a good deal of it being an imperfect substitute for clear thinking, that he hesitated to regard Sir Gilbert Walker as a public benefactor. As regards Σx^2 and Σy^2 there was little economy in using one figure rather

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than two or three, in view of the existence of tables of squares like that in Crelle's tables. One need not add up all the columns. Even as regards Σxy, one of the two factors was often naturally a single figure. A multiplication table up to 99 might over-burden the memory, but it did not require much space.

Sir GILBERT WALKER, in reply, in reference to what Mr. Brooks had said, thought it was to be recognised that there were cases in which we were interested in the relationships between the general sweep of the curve, *i.e.*, the secular change, and cases in which we were interested in the detail upon it, *i.e.*, the surges of short duration. The two problems may be quite different and in the first case we may if we wish get rid of the details by smoothing, while in the second we may subtract from the actual the ordinates of the smoothed curve and examine the relations of the short surges. He was anxious to warn people about working with changes because, some years ago in India, they were deceived by this in a formula for forecasting the rainfall: the graph of the rainfall of any year, and that of the pressure in India of the previous year moved in parallel directions, and these curves suggested a positive correlation which was not real. The cause of this anomalous behaviour was that rainfall of any year and pressure of the same year moved in opposite directions, so that there was a close resemblance to the diagram which had just been shown on the screen. They had been deceived and anybody else was liable to be deceived unless he took the necessary precautions to see what the correlation was between the data used for forecasting the rains of a particular year and the rainfall of the year previous.

APPENDIX ADDED DECEMBER 28, 1925.

In response to requests for a worked example of the effect of the proposed method, the relationship between the Ohio rainfall of June and July and the yield of potatoes there is given in Table I., as calculated in the ordinary manner by J. Warren Smith in the *Monthly Weather Review*, Washington, 1911, p. 793, and in Table II. the abbreviated method is adopted; Table I. is followed by the original explanation.

"Column No. 1 shows the years; No. 2 the total rainfall for Ohio for June and July, in inches and tenths; No. 3 the departure from the normal rainfall for these two months, the normal for 54 years being 8.1 inches; No. 4 the square of the departure as shown in column 3; No. 5 gives the yield of potatoes for Ohio in bushels per acre; No. 6 the departure from the normal potato yield, the average potato yield for the 27 years under consideration being 74 bushels per acre; No. 7 the square of the departure in column 6; column No. 8 shows the product of the departures in columns 3 and 6."

"To determine the correlation coefficient, r, divide the algebraic sum of the values in column 8 by the square root of the product of the sums of columns 4 and 7. The calculation in this case is $101.53 \times 9367 = 951031.51$. The square root of this product is 975.20; 484.1 divided by $975.20 = 0.50$, the correlation coefficient."

Columns x and y are the old columns 3 and 6. We first have to find Σx^2 and Σy^2, and for this purpose it is convenient to make use of a table of abbreviated squares in which the unit digit is omitted and the nearest ten taken. The squares may be summed

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on a comptometer without writing them out; we find $\Sigma x^2 = 10190$, $\Sigma y^2 = 9390$.

TABLE I.—THE ORDINARY METHOD.

Year.	Rainfall.			Yield.			Product of Columns 3 and 6.
	Rainfall.	Departure.	Square of Col. 3.	Yield.	Departure.	Square of Col. 6.	
1.	2.	3.	4.	5.	6.	7.	8.
	inches.	inches.		bush.	bush.		
1883	8.4	0.3	0.09	99	25	625	+7.5
1884	6.8	−1.3	1.69	75	1	1	−1.3
1885	7.5	−0.6	0.36	75	1	1	−0.6
1886	6.4	−1.7	2.89	78	4	16	−6.8
1887	5.9	−2.2	4.84	30	−44	1936	+96.8
1888	7.8	−0.3	0.09	80	6	36	−1.8
1889	8.3	0.2	0.04	75	1	1	+0.2
1890	6.5	−1.6	2.56	46	−28	784	+44.8
1891	8.6	0.5	0.25	98	24	576	+12.0
1892	9.4	1.3	1.69	60	−14	196	−18.2
1893	5.8	−2.3	5.29	58	−16	256	+36.8
1894	4.2	−3.9	15.21	63	−11	121	+42.9
1895	4.5	−3.6	12.96	63	−11	121	+39.6
1896	12.9	4.8	23.04	89	15	225	+72.0
1897	7.5	−0.6	0.36	42	−32	1024	+19.2
1898	6.8	−1.3	1.69	61	−13	169	+16.9
1899	7.1	−1.0	1.00	71	−3	9	+3.0
1900	7.6	−0.5	0.25	76	2	4	−1.0
1901	7.2	−0.9	0.81	54	−20	400	+18.0
1902	12.2	4.1	16.81	94	20	400	+82.0
1903	7.7	−0.4	0.16	83	9	81	−3.6
1904	7.0	−1.1	1.21	98	24	576	−26.4
1905	8.6	0.5	0.25	78	4	16	+2.0
1906	8.6	0.5	0.25	110	36	1296	+18.0
1907	9.9	1.8	3.24	76	2	4	+3.6
1908	6.6	−1.5	2.25	77	3	9	−4.5
1909	9.6	1.5	2.25	96	22	484	+33.0
Summary			101.53			9367	+484.1

Now, using a slide rule, we set 27 (the number of years) against 10190 on the upper scale (the scale of squares) and read off the value of the square root of 10190/27 on the lower scale; this, of course, is the S.D. Another setting of the slide rule will give $\sqrt{20}$/S.D. = .230 which is the required factor for reducing x to x' of which the S.D. is to be $\sqrt{20}$. Similarly y' is obtained by multiplying y by .240.

The summation of $x' \times y'$ is done directly on the comptometer, using both hands and using the columns to the right and left of the centre for + and − product respectively: we find $\Sigma xy = 309 - 37 = +272$. The product of the S.D.'s of x' and y' being 20 ($\sqrt{20} \times \sqrt{20}$) we have, finally, $r = +272/20 \times 27 = .50$, as before. It will be noticed that the biggest product of x', y' is 55, while of x, y it is 968.

It is useful to have x' and y' written out on separate sheets or strips of paper, so that if, as is often the case, x' is to be correlated

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with other factors besides y', all that is necessary is to place the appropriate sheets side by side, sum the products and divide by 20 times the number of years.

TABLE II.—THE SHORTENED METHOD.

Original departures.		Reduced departures.		
x	y	x^1	y^1	
3	25	1	6	
−13	1	−3	0	
−6	1	−1	0	
−17	4	−4	1	
−22	−44	−5	−11	
−3	6	−1	1	
2	1	0	0	
−16	−28	−4	−7	
5	24	1	6	
13	−14	3	−3	
−23	−16	−5	−4	
−39	−11	−9	−3	The values of Σx^2, Σx^2 and $\Sigma x^1 y^1$ are added on the comptometer without writing them down.
−36	−11	−8	−3	
48	15	11	4	
−6	−32	−1	−8	
−13	−13	−3	−3	
−10	−3	−2	−1	
−5	2	−1	0	
−9	−20	−2	−5	
41	20	9	5	
−4	9	−1	2	
−11	24	−3	6	
5	4	1	1	
5	36	1	9	
18	2	4	0	
−15	3	−3	1	
15	22	3	5	

The Optics of the Sunshine Sphere.

A useful and interesting account of the optics of the sunshine recorder is contributed by E. G. Bilham to the February number of the *Meteorological Magazine*.

In connection with the adjustment of the cards it is found that a card outside the focal distance shows little tendency to burn until a position is reached within a tenth of an inch from the focus. On the other hand, when the card is between the focus and the sphere, burning takes place freely up to a point within half an inch of the lens. Thus for a sphere to be too short in focus is a much more serious fault than an error in the opposite direction.

Lack of uniformity, however, in the material of the sunshine ball has little effect on the burning power. A badly striated sphere gave results quite comparable with these from a very clear ball used as a standard.

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ON THE DYNAMICS OF GEOSTROPHIC WINDS.*

By HAROLD JEFFREYS, M.A., D.Sc., F.R.S.

[Received June 27—Read December 16, 1925.]

1. *Introduction.*

In an earlier paper[1] I defined a geostrophic wind as one such that the pressure terms in the equations of horizontal motion are balanced mainly by the terms that involve the earth's speed of rotation. All terrestrial winds of great horizontal extent belong to this class. The present paper is an attempt to determine what winds would be expected to arise on dynamical principles from certain distributions of temperature. If the level surfaces within the atmosphere were isothermal no winds could exist; but actually the air is heated in such a way as to produce appreciable differences of temperature over the level surfaces, and accordingly winds are maintained. The actual distribution of temperature is here regarded as given, so that considerations as to how the heat supplied from the sun is redistributed in the atmosphere by radiation, convection, and turbulence do not enter. It is found that such problems have an intimate relation to the theory of the tides in a homogeneous incompressible ocean of uniform depth (different from that given by Margules). The depth of such an ocean must be rather less than the height of the homogeneous atmosphere. The disturbing potential of the tidal theory is replaced by a function of the mean conditions over the level surfaces and of the departures of the temperatures from mean values over level surfaces. The solution can be found by known methods when friction is ignored. Fair quantitative agreement with observation is obtained when the theory is applied to the monsoons; application to the diurnal and semi-diurnal motions would probably be possible, but has not been carried out here. The nature of the general circulation, in the absence of friction, has been determined, but is such that friction would introduce serious modifications. A discussion of the nature of these modifications is given, and indicates the dynamical necessity for a permanent region of low pressure around each pole, with a continual interchange of air between high and low latitudes by means of cyclones. These must apparently, if they are to produce the required effect, have a structure not unlike that described by Bjerknes. It appears, however, that friction must play the most important part in producing them in the first place.

2. *The analogy between tides and large-scale motions of the atmosphere.*

It was shown in the paper already mentioned that the equations of motion of the atmosphere can be written, with much greater accuracy than is ever required, in the form

$$\rho\left(\frac{du}{dt} - 2\omega v\cos\theta\right) = -\frac{1}{R}\frac{\partial p}{\partial\theta} + F \quad . \quad . \quad (1)$$

* See note in reference to this paper on p. 126.

[1] "On the Dynamics of Wind," *Q.J.R.Meteor.Soc.*, **48**, 1922, pp. 29-47.

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with other factors besides y', all that is necessary is to place the appropriate sheets side by side, sum the products and divide by 20 times the number of years.

TABLE II.—The Shortened Method.

Original departures.		Reduced departures.		
x	y	x^1	y^1	
3	25	1	6	
−13	1	−3	0	
−6	1	−1	0	
−17	4	−4	1	
−22	−44	−5	−11	
−3	6	−1	1	
2	1	0	0	
−16	−28	−4	−7	
5	24	1	6	
13	−14	3	−3	
−23	−16	−5	−4	
−39	−11	−9	−3	The values of Σx^2, Σx^2 and $\Sigma x^1 y^1$ are added on the comptometer without writing them down.
−36	−11	−8	−3	
48	15	11	4	
−6	−32	−1	−8	
−13	−13	−3	−3	
−10	−3	−2	−1	
−5	2	−1	0	
−9	−20	−2	−5	
41	20	9	5	
−4	9	−1	2	
−11	24	−3	6	
5	4	1	1	
5	36	1	9	
18	2	4	0	
−15	3	−3	1	
15	22	3	5	

The Optics of the Sunshine Sphere.

A useful and interesting account of the optics of the sunshine recorder is contributed by E. G. Bilham to the February number of the *Meteorological Magazine*.

In connection with the adjustment of the cards it is found that a card outside the focal distance shows little tendency to burn until a position is reached within a tenth of an inch from the focus. On the other hand, when the card is between the focus and the sphere, burning takes place freely up to a point within half an inch of the lens. Thus for a sphere to be too short in focus is a much more serious fault than an error in the opposite direction.

Lack of uniformity, however, in the material of the sunshine ball has little effect on the burning power. A badly striated sphere gave results quite comparable with these from a very clear ball used as a standard.

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ON THE DYNAMICS OF GEOSTROPHIC WINDS.*

By HAROLD JEFFREYS, M.A., D.Sc., F.R.S.

[Received June 27—Read December 16, 1925.]

1. *Introduction.*

In an earlier paper[1] I defined a geostrophic wind as one such that the pressure terms in the equations of horizontal motion are balanced mainly by the terms that involve the earth's speed of rotation. All terrestrial winds of great horizontal extent belong to this class. The present paper is an attempt to determine what winds would be expected to arise on dynamical principles from certain distributions of temperature. If the level surfaces within the atmosphere were isothermal no winds could exist; but actually the air is heated in such a way as to produce appreciable differences of temperature over the level surfaces, and accordingly winds are maintained. The actual distribution of temperature is here regarded as given, so that considerations as to how the heat supplied from the sun is redistributed in the atmosphere by radiation, convection, and turbulence do not enter. It is found that such problems have an intimate relation to the theory of the tides in a homogeneous incompressible ocean of uniform depth (different from that given by Margules). The depth of such an ocean must be rather less than the height of the homogeneous atmosphere. The disturbing potential of the tidal theory is replaced by a function of the mean conditions over the level surfaces and of the departures of the temperatures from mean values over level surfaces. The solution can be found by known methods when friction is ignored. Fair quantitative agreement with observation is obtained when the theory is applied to the monsoons; application to the diurnal and semi-diurnal motions would probably be possible, but has not been carried out here. The nature of the general circulation, in the absence of friction, has been determined, but is such that friction would introduce serious modifications. A discussion of the nature of these modifications is given, and indicates the dynamical necessity for a permanent region of low pressure around each pole, with a continual interchange of air between high and low latitudes by means of cyclones. These must apparently, if they are to produce the required effect, have a structure not unlike that described by Bjerknes. It appears, however, that friction must play the most important part in producing them in the first place.

2. *The analogy between tides and large-scale motions of the atmosphere.*

It was shown in the paper already mentioned that the equations of motion of the atmosphere can be written, with much greater accuracy than is ever required, in the form

$$\rho\left(\frac{du}{dt} - 2\omega v\cos\theta\right) = -\frac{1}{R}\frac{\partial p}{\partial\theta} + F \quad . \quad . \quad (1)$$

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[1] "On the Dynamics of Wind," *Q.J.R.Meteor.Soc.*, **48**, 1922, pp. 29-47.

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$$\rho\left(\frac{dv}{dt}+2\omega u\cos\theta\right)=-\frac{1}{\varpi}\frac{\partial p}{\partial\phi}+G \quad . \quad . \quad (2)$$

$$0=-g\rho-\frac{\partial p}{\partial z} \quad . \quad . \quad . \quad . \quad (3)$$

In these equations ρ is the density, θ the co-latitude, ϕ the east longitude, z the height above sea-level and t the time; p denotes the pressure, u the velocity southwards, v eastwards and w upwards; R is the radius of curvature of the meridian at sea-level, and ϖ the distance of the particle considered from the axis of the earth; g is the acceleration due to gravity, and ω the earth's angular velocity of rotation; F and G are the southward and eastward components of frictional force per unit volume.

In a state of equilibrium the pressure and density must be constant over a set of surfaces which, with sufficient accuracy, may be identified in a shallow atmosphere such as ours with the surfaces of uniform height above sea-level. Let the suffix zero attached to any quantity indicate that the value of that quantity at the same position in the equilibrium state is meant, and let an accent indicate the departure from the equilibrium value; thus, for instance,

$$p=p_0+p';\ \rho=\rho_0+\rho' \quad . \quad . \quad . \quad . \quad (4)$$

Evidently p_0 and ρ_0 are functions of z alone, while (3) gives

$$g\rho_0+\frac{\partial p_0}{\partial z}=0 \quad . \quad . \quad . \quad . \quad (5)$$

The equation of continuity is

$$\frac{\partial\rho}{\partial t}+\frac{1}{R\varpi}\frac{\partial}{\partial\theta}(\rho\varpi u)+\frac{1}{\varpi}\frac{\partial}{\partial\phi}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0 \quad . \quad . \quad (6)$$

The pressure and the density tend to zero at a great height; hence (3) gives

$$p=\int_z^\infty g\rho dz \quad . \quad . \quad . \quad . \quad . \quad (7)$$

In this equation, and in others with infinity as the upper limit, it is legitimate to ignore the variation of gravity with height; for the density falls off with height so rapidly that where the value of gravity differs appreciably from its value at sea level the density is so small that only a negligible contribution is made to the integral.

If now we consider only small deviations from rest relative to the rotating earth, u, v, w and ρ' are all small, and we may neglect their squares and products. Thus d/dt can be replaced everywhere by $\partial/\partial t$, and ρu, ρv, ρw by $\rho_0 u$, $\rho_0 v$, $\rho_0 w$.

Let us now integrate (6) from sea-level up to a great height. Subject to the approximations just made, the first term gives, by (7), $\frac{1}{g}\frac{\partial p_s}{\partial t}$ where p_s is the pressure at sea-level. The last term gives simply the difference between the values of ρw at sea-level and a great height. Both of these are zero; that at sea level because w is there zero, and that at a great height because if it were finite it would imply a loss of matter from the earth at the top of the atmosphere. If then we denote $\int_0^\infty \rho_0 u dz$ by U, and $\int_0^\infty \rho_0 v dz$ by V,

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the equation becomes

$$\frac{1}{g}\frac{\partial p_s}{\partial t}+\frac{1}{R\varpi}\frac{\partial}{\partial\theta}(\varpi U)+\frac{1}{\varpi}\frac{\partial V}{\partial\phi}=0 \quad . \quad . \quad . \quad (8)$$

Similarly we may integrate (1) and (2) with regard to the height. If we write P for $\int_0^\infty p dz$, they become

$$\frac{\partial U}{\partial t}-2\omega V\cos\theta=-\frac{1}{R}\frac{\partial P}{\partial\theta}+\int_0^\infty F dz \quad . \quad . \quad (9)$$

$$\frac{\partial V}{\partial t}+2\omega U\cos\theta=-\frac{1}{\varpi}\frac{\partial P}{\partial\phi}+\int_0^\infty G dz \quad . \quad . \quad (10)$$

Evidently the integrals that constitute the last terms of these equations represent the total frictional force acting on a column of air of unit horizontal section. There being no friction at the top of the atmosphere, these integrals depend only on the skin friction over the ground and on the shearing stresses across vertical planes.

Suppose now that

$$p=R'\rho T \quad . \quad . \quad . \quad . \quad (11)$$

where R' is a constant. In an atmosphere consisting of a perfect gas of uniform composition T would be the absolute temperature; but in the actual atmosphere T will differ somewhat from the absolute temperature, on account of variations from place to place in composition, and especially in humidity. It will be called the virtual temperature. We have from (3)

$$\frac{\partial p}{\partial z}=-\frac{gp}{R'T} \quad . \quad . \quad . \quad . \quad (12)$$

whence

$$p=p_s\exp\left(-\int_0^\infty\frac{gdz}{R'T}\right). \quad . \quad . \quad . \quad (13)$$

We can now obtain a relation between the time-variations of P and p_s. Any change of the distribution of pressure in the column of air over a place can be supposed carried out in two stages. First, new air can be added to the column at every height in such a way as to change p_s to the appropriate new value, without change of temperature at any height. We see from (13) that this will change the pressure at all heights in the same ratio. Thus, at a definite height z, p will be increased by $p'_s\,p_0/p_{s0}$, to the first order. Next, let the air at all heights be heated or cooled to the new temperatures, the changes of temperature by hypothesis being small, without any horizontal outflow taking place, so that p_s is not altered. Then, since the absence of outflow ensures that the column of air retains the original cross section, the height of any element dz becomes Tdz/T_0, and therefore the air at height z is lifted a distance $\int_0^z\frac{T'dz}{T_0}$. Thus a layer of air of this thickness, which was formerly below the level z, is now above that level, and its weight, by (3),

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must now be balanced by the pressure at z. Thus the pressure at z is increased by $g\rho_0 \int_0^z \frac{T'dz}{T_0}$. In all, therefore,

$$p' = \frac{p_0}{p_{s0}} p'_s + g\rho_0 \int_0^z \frac{T'dz}{T_0} \quad . \quad . \quad . \quad (14)$$

Integrating with regard to z, we obtain

$$P' = \frac{P_0}{p_{s0}} p'_s + \int_0^\infty g\rho_0 \int_0^z \frac{T'dz}{T_0} dz \quad . \quad . \quad (15)$$

This may now be used to eliminate $\partial p_s/\partial t$ from (8). We find

$$\frac{1}{g}\frac{\partial P'}{\partial t} - \int_0^\infty \rho_0 \int_0^z \frac{1}{T_0}\frac{\partial T}{\partial t} dzdz + \frac{P_0}{p_{s0}}\left[\frac{1}{R\varpi}\frac{\partial}{\partial\theta}(\varpi U) + \frac{1}{\varpi}\frac{\partial V}{\partial\phi}\right] = 0 \quad (16)$$

Now let us compare (9), (10) and (16) with the equations occurring in the theory of slow tidal motions in an incompressible ocean of uniform depth. The latter are

$$\frac{\partial u}{\partial t} - 2\omega v\cos\theta = -\frac{g}{R}\frac{\partial}{\partial\theta}(\zeta - \xi) + F_1 \quad . \quad . \quad (17)$$

$$\frac{\partial v}{\partial t} + 2\omega u\cos\theta = -\frac{g}{\varpi}\frac{\partial}{\partial\phi}(\zeta - \xi) + G_1 \quad . \quad . \quad (18)$$

$$\frac{\partial\zeta}{\partial t} + \frac{h}{R\varpi}\frac{\partial}{\partial\theta}(\varpi u) + \frac{h}{\varpi}\frac{\partial v}{\partial\phi} = 0 \quad . \quad . \quad (19)$$

Here ζ is the elevation of the free surface, ξ is the height of the equilibrium tide, F_1 and G_1 are the components of the frictional force per unit volume, averaged through the depth, h is the depth of the ocean, and the other symbols have meanings analogous to those they bear in the meteorological problem.

We see at once that, if U and V are to correspond to u and v respectively, P' must correspond to $g(\zeta - \xi)$, F_1 and G_1 with $\int_0^\infty F dz$ and $\int_0^\infty G dz$, P_0/p_{s0} with h, and $P' - \int_0^\infty \rho_0 \int_0^z g\frac{T'dz}{T_0} dz$ with $g\zeta$. With these substitutions the analogy between the two problems is complete. If in the tidal problem we write ζ' for $\zeta - \xi$, P' corresponds to ζ', and $\int_0^\infty \rho_0 \int_0^z \frac{T'dzdz}{T_0}$ with $-\zeta$.

If then the tidal problem is solved for the appropriate values of ξ and the frictional forces, the results can be adapted immediately to give the values of P', U and V in the meteorological problem, and then from (8) or (15) we can find the variation of p_s. Thus for every problem of the motion of the atmosphere produced by changes of temperature or composition over large regions of the earth's surface there is a corresponding tidal problem, whose solu-

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tion, if known, will enable us to infer that of the meteorological problem.

In this discussion the actual distribution of virtual temperature is supposed to be among the data of the problem. The same methods could be applied if we were given the rate of supply of heat to all parts of the atmosphere from outside, but then an extra differential equation would have to be included, expressing the conditions of heat transference. Since the distribution of temperature is better known than the theory of the transfer of heat in the atmosphere, it seems better in the present state of knowledge to use the former as the starting point of the dynamical theory. It must be noticed, however, that in some of the free oscillations of the atmosphere temperature changes will be produced by the pressure changes that occur, and these must be allowed for if the theory is applied to such oscillations.

The depth of the equivalent ocean is P_0/p_{s0}, which can be found roughly from the results of W. H. Dines,[2] who has tabulated the pressure and density at intervals of 1 km. up to 20 km. above sea level at numerous stations. The value of $\int p dz$ from sea level up to 20 km. has been found by means of the Gregory formula for single integration.[3] The integral from 20 km. up to an indefinitely great height can be easily found; for T is practically constant at these heights, except where the height is so great that the density is too small to affect the result, so that this integral can be calculated from the pressure and density at 20 km. as for an isothermal atmosphere. Its value is $p^2/g\rho$ evaluated for 20 km.

The results are as follows. All are annual means.

	p_s	$\int_0^{20} p dz$	$\int_{20}^{\infty} p dz$	$\int_0^{\infty} p dz$	P/p_s	H
England S.E. ...	1014	7033	353	7386	7.28	8.24
Equator	1012	7287	314	7601	7.51	8.78

All pressures are in millibars and all heights in kilometres. The probable error of P, given p_s, does not exceed 4 units. The last column gives the height of the homogeneous atmosphere, calculated as $p_s/g\rho_s$. It is seen that the depth of the equivalent ocean is less variable than that of the homogeneous atmosphere and distinctly smaller. In an atmosphere at rest both would of course be constant. In investigating the theory of atmospheric motions mean values over the surface of the earth are really required, but since these are not available, and since the error will in any case be of the second order, it will be assumed in what follows that the depth of the equivalent ocean is 7.30 km.

3. *Periodic and steady motions without friction.*

The above theorem finds an immediate application when the temperature disturbances are periodic functions of the time or expressible as sums of such functions and friction is ignored. The

[2] "The Characteristics of the Free Atmosphere," *Meteor. Office, Geophys. Mem.* No. 13, 1919, p. 63.

[3] Whittaker and Robinson, *Calculus of Observations*, 1924, p. 143.

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analogous tidal problem can in any such case be solved completely by known methods; either the method of Laplace or that of Hough may be used.[4] Thus every problem of this type may be regarded as soluble.

Certain periodic motions of a gas covering a rotating spheroid have been considered by Margules,[5] who showed that they could be reduced to analogous tidal problems; but Margules's solutions are inapplicable to the atmosphere, an important boundary condition being incorrect in his work. He assumes that there is no vertical motion in the atmosphere, which amounts to supposing the atmosphere enclosed within a rigid external boundary. To prevent vertical motion, variations of pressure over this boundary are necessary; whereas the actual atmosphere is not in contact at the top with anything capable of exerting pressure. The correct boundary condition is that the atmosphere is under no stress from outside, which is what has been assumed in the present paper. The theorem just proved differs from Margules's result in two respects: I find that, if U and V are eliminated, $\int_0^\infty p dz$ satisfies the same differential equation as is satisfied by ζ' in the theory of the tides, whereas Margules finds that this equation is satisfied by p; and in my theory the depth of the equivalent ocean is P_0/p_{s0}, whereas in that of Margules it is the height of the homogeneous atmosphere $p_{s0}/g\rho_{s0}$. It may be noted that P/p_s is the height of the centre of mass of a vertical column.

3.1. *The monsoons and similar winds.*

A problem readily soluble by methods akin to those used in tidal theory is that of a periodic wind produced by local heating, so that the pressure changes within a certain region, small in area in comparison with an octant of the earth's surface, are great in comparison with the changes elsewhere. In such a case we may ignore variations of θ within the region affected and replace $\omega\cos\theta$ by a constant Ω. Let us suppose that all changes are proportional to $e^{i\gamma t}$, where γ is a constant, and take polar coordinates r and ϕ in the earth's surface,[6] the origin being near the centre of the region considered. Then the equations 2 (9) and (10) transform in the usual way to

$$i\gamma U - 2\Omega V = -\frac{\partial P}{\partial r} \quad . \quad . \quad . \quad . \quad (1)$$

$$2\Omega U + i\gamma V = -\frac{1}{r}\frac{\partial P}{\partial \phi} \quad . \quad . \quad . \quad . \quad (2)$$

where U and V are now the results of treating the radial and transverse velocities as in chapter 2. Solving these we have

$$U = -\frac{1}{4\Omega^2 - \gamma^2}\left(i\gamma\frac{\partial P}{\partial r} + \frac{2\Omega}{r}\frac{\partial P}{\partial \phi}\right) \quad . \quad . \quad (3)$$

$$V = -\frac{1}{4\Omega^2 - \gamma^2}\left(\frac{i\gamma}{r}\frac{\partial P}{\partial \phi} - 2\Omega\frac{\partial P}{\partial r}\right) \quad . \quad . \quad . \quad (4)$$

[4] Accounts of both methods, with references, are given in Lamb's *Hydrodynamics*.

[5] *Wien, Sitzber. Ak. Wiss.*, **99** (iia), 1890, pp. 204-227; **101** (iia), 1892, pp. 597-620, **102** (iia), 1893, pp. 11-56, 1369-1421.

[6] In previous sections ϕ has been used to denote the longitude, but no confusion can arise.

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At the same time 2 (16) transforms into

$$i\gamma P' + gh\left[\frac{1}{r}\frac{\partial}{\partial r}(rU) + \frac{\partial V}{r\partial\phi}\right] = i\gamma g\int_0^\infty \rho_0 \int_0^z \frac{T'}{T_0} dzdz \quad . \quad (5)$$

$$= i\gamma Q \quad . \quad . \quad . \quad . \quad . \quad (6)$$

say. Here h is the depth of the equivalent ocean. Substituting in this from (3) and (4), and cancelling the factor $i\gamma$, we have

$$-\frac{gh}{4\Omega^2-\gamma^2}\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial P'}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 P'}{\partial\phi^2}\right]+P'=Q \quad . \quad (7)$$

Now Q can always be expressed as the sum of terms of the form

$$Q_n = AJ_n(\lambda r)\exp(i\gamma t \pm in\phi) \quad . \quad . \quad . \quad (8)$$

where A and λ are constants and n is a positive integer. Then (7) is satisfied by making P' the sum of terms of the form $BJ_n(\lambda r)\exp(i\gamma t \pm in\phi)$. For if P' is equal to a term of this form,

$$r\frac{\partial}{\partial r}\left(r\frac{\partial P'}{\partial r}\right)+(\lambda^2 r^2 - n^2)P' = 0 \quad . \quad . \quad . \quad (9)$$

and (7) is equivalent to

$$\left(\frac{gh\lambda^2}{4\Omega^2-\gamma^2}+1\right)B = A \quad . \quad . \quad . \quad (10)$$

Thus the general solution is obtained, except in the special case when the coefficient of B in (10) vanishes; if such a case were to arise special treatment would be necessary. It is enough to notice at present that the coefficient is essentially positive when γ is less than 2Ω; thus the solution will succeed for all periods much exceeding a day.

Returning now to 2 (15) we have

$$hp'_s = P' - Q$$

$$= -Q\Big/\left(1+\frac{4\Omega^2-\gamma^2}{gh\lambda^2}\right) \quad . \quad . \quad . \quad (11)$$

Two extreme cases evidently arise, according as the second term in the denominator is large or small. If the horizontal extent of the disturbance is very great, so that λ is very small, we see that hp'_s/Q is very small. Thus temperature disturbances over a very large region give rise to small changes of surface pressure. The horizontal extent being great, the pressure gradients are small for two reasons, and therefore there are only slight winds at sea level. If, however, the horizontal extent is small, and thus λ great, P'/Q is small, and we have approximately

$$p'_s = -Q/h \quad . \quad . \quad . \quad . \quad (12)$$

Consider now the critical value of λ that makes $(4\Omega^2-\gamma^2)/gh\lambda^2$ equal to unity. If the latitude is 45°, we have approximately

$$\Omega = 5\times10^{-5}/1 \text{ sec.}; \quad g = 981 \text{ cm.}^2/\text{sec.}; \quad h = 7.3\times10^6 \text{ cm.},$$

while for all motions of long period γ^2 is very small compared with $4\Omega^2$. Thus

$$\frac{gh}{4\Omega^2-\gamma^2} = 7.1\times10^{16} \text{ cm.}^2 \quad . \quad . \quad . \quad (13)$$

and the critical value of $1/\lambda$ is 2.7×10^8 cm. or 2700 km.

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A direct comparison of the theory with observation is difficult, on account of the permanent general circulation over the earth, which in most places overwhelms the changes due to periodic local heating. The only exceptions are Asia and, possibly, Antarctica. The extent of Asia along a central meridian, omitting the projections of southern India and Indo-China, amounts to 55° of latitude, or about 6000 km. Thus it is comparable with the size above found to be critical; further, it is so large that the variations of $\cos\theta$ within the region affected will produce appreciable effects. As a first approximation let us give θ its mean value, about 45°, and suppose that λ has just its critical value. Then p'_s should be equal to $-Q/2h$.

The annual variation of temperature at great heights in Central Asia is unfortunately unknown. If we make the simple assumption that it varies in the same ratio at all heights, we can write

$$Q=\frac{gT'_s}{T_{os}}\int_0^\infty \rho_0 z\,dz \quad . \quad . \quad . \quad . \quad (14)$$

But

$$\int_0^\infty g\rho z\,dz=-\int z\,dp=-[pz]_0^\infty+\int_0^\infty p\,dz=P \quad . \quad . \quad (15)$$

since the integrated portion vanishes at both limits. Thus

$$Q=\frac{T'_s}{T_{os}}P_0 \quad . \quad . \quad . \quad . \quad (16)$$

But

$$h=P_0/p_0 \quad . \quad . \quad . \quad . \quad (17)$$

and we have simply

$$p'_s=-\frac{Q}{2h}=-\tfrac{1}{2}\frac{T'_s}{T_{so}}p_{-0} \quad . \quad . \quad . \quad (18)$$

1 Recent values of the annual variations of temperature and pressure are given in Sir Napier Shaw's "*The Air and Its Ways*," Plates IV., V., XX., XXI. The range of temperature at sea-level in Mongolia, about midway between Lakes Baikal and Balkash, is about 75°F. from January to July, the mean being about 40°F. The absolute zero of temperature being −459°F., we can take T_{so} as 499°, and then by (18) the annual range of pressure should be practically 75 mb. The actual range is about 30 mb. Thus the theory implies an annual variation of pressure decidedly greater than is observed. The difference is probably due to the temperature at great heights varying in the course of the year to a smaller relative extent than the temperature at the surface. In the paper already quoted, Dines finds from Patterson's observations that in the stratosphere over Canada, where the conditions resemble those of Central Asia more closely than in any other place that we have data for, the annual temperature range is only about a quarter of what it is at the surface, and the phase is reversed. By a rough numerical calculation from Dines's figures, I find that if the annual variations at various heights in Canada and Central Asia were in proportion, the value of Q would have to be multiplied by 0.55, and the annual pressure variation then becomes 41 millibars. This is near enough to the truth to warrant the hope that the principal factors of the problem have been taken into account.

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The formula 2 (14) may be used to find the height where the annual pressure variation vanishes. Assuming 41 mb. for the annual range of pressure at sea level, and 0.15 for T'/T_0 at all heights, the vanishing of p' gives an equation for z, which is satisfied if z is 2.1 km. Thus the monsoon should be reversed in direction above this height. The layer where the annual variations of pressure and temperature are systematically opposite in sign is therefore comparatively shallow. This result is not merely a result of the present theory, for it would follow equally if the pressures at various heights were calculated from the observed surface pressures. I know of no relevant data for upper air winds in Central Asia. The reversal of the monsoon, if it occurs at any height in India, does so at a much higher level; but the monsoon in India is subsidiary to the pressure changes in Central Asia, and cannot play a large part in producing them, on account of the small size of India compared with Asia as a whole. Further, Indian conditions are probably much affected by the mechanical obstruction to movement afforded by the Himalayas. The height found here is comparable with an estimate by G. C. Simpson[7] on the Antarctic Continent, which was 1.7 km. by calculation from the surface temperature and pressure, and less than 4 km. by observation of the smoke from Mt. Erebus.

3.11. The results of this section may be compared with those of an earlier paper,[8] in which the motions due to periodic temperature changes in a homogeneous incompressible fluid layer were investigated. If we ignore the effect of friction, which was considered in the paper mentioned but found to be small, the pressure variation on the ground in such an atmosphere is nearly zero for a large enough region, but for a small region it is $-\frac{1}{2}g\rho\alpha T'H$, where α is the coefficient of volume expansion, T' the variation of temperature, supposed the same at all heights, and H is the depth. Comparing this with the present discussion, we see that in a homogeneous atmosphere the undisturbed pressure is $g\rho_0(H-z)$, so that P_0 is $\frac{1}{2}g\rho_0H^2$ and the depth of the equivalent ocean is $\frac{1}{2}H$. Further, by 3.1 (6),

$$Q=\tfrac{1}{2}g\rho_0\alpha T'H^2 \quad . \quad . \quad . \quad . \quad (1)$$

in the present conditions, so that in a small region we should have by 3.1 (12)

$$p'_s=-g\rho_0\alpha T'H \quad . \quad . \quad . \quad . \quad (2)$$

just double what was found in the earlier paper. The discrepancy arises from the fact that the results of the present paper have been derived essentially for an atmosphere of indefinite height, obeying Boyle's law, and cannot be applied directly to a homogeneous atmosphere of finite height. In a homogeneous atmosphere, indeed, 2 (14) is replaced by

$$p'=p'_s+g\rho_0\alpha\int_0^z T'dz \quad . \quad . \quad . \quad . \quad (3)$$

and on integrating with regard to the depth we have

$$P'=Hp'_s+g\rho_0\alpha\int_0^H\int_0^z T'dzdz \quad . \quad . \quad . \quad (4)$$

[7] *Brit. Ant. Exp. Rept.*, 1910-13, **1**, p. 136.
[8] *Phil. Mag.*, **34**, 1917, 449-458.

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The treatment of the equations of motion is as before, but we see from this equation that the depth of the equivalent ocean is not P_0/p_{s0} as formerly defined, but H. The difference arises from the presence in 2 (14), for the actual atmosphere, of the factor p_0/p_{s0}, which is a function of z, but which is replaced by unity for the homogeneous atmosphere.

3.12. Reference may be made at this stage to a property of the extreme case of slow periodic motion, namely, steady motion. It is easy to prove that the inflow of air into a vertical column contains the factor γ, and therefore is zero at all heights in a steady motion. Further, if the temperature distribution is steady no expansion is taking place within the column. Hence there is no vertical motion anywhere. Yet in this case P' will still satisfy 3.1 (7), and there will be steady horizontal winds. When the region affected is so large that differences of latitude within it must be taken into account, this result requires some modification; but it remains exactly true (as is physically almost obvious) when the distribution of temperature and pressure is symmetrical about the axis of rotation. It appears desirable to point out this fact, since meteorologists habitually speak of circulation in vertical planes as essential to the maintenance of atmospheric motion. Vertical motion is essential to the initiation of a pressure disturbance by heating, but when the appropriate redistribution of pressure has taken place it can in many cases maintain itself permanently without vertical motion; and indeed since the system here contemplated is a non-dissipative one and steady, the vertical motion must in those cases where it occurs absorb just as much energy as it renders available. In the actual atmosphere friction produces a loss of energy and a drift of air across the isobars, which must lead to a slow vertical motion; but friction and vertical motion alike are only secondary phenomena of atmospheric motion, appearing only after the primary agencies, namely rotation, density changes and acceleration have done their work.

3.2. *The General Circulation.*

Let us now apply the same methods to the theory of the general circulation. The whole distribution will be supposed symmetrical about the polar axis and not changing with the time. The notation of §2 is reintroduced. The indeterminateness of such a problem of slow steady motion[9] will be met by regarding the steady motion as the limit of a periodic motion when the period becomes very long. In these conditions V is independent of ϕ, while

$$U = -\frac{i\gamma}{4\omega^2 \cos^2\theta - \gamma^2} \frac{\partial P}{R\partial\theta} \quad . \quad . \quad . \quad (1)$$

and 2 (16) gives on cancelling a factor $i\gamma$

$$-\frac{gh}{R\varpi}\frac{\partial}{\partial\theta}\left(\frac{\varpi}{4\omega^2\cos^2\theta}\frac{\partial P}{R\partial\theta}\right) + P = Q \quad . \quad . \quad (2)$$

where

$$Q = \int_0^\infty g\rho_0 \int_0^z \frac{T'}{T}\, dzdz \quad . \quad . \quad (3)$$

[9] *Cf.* Lamb, *Hydrodynamics*, §214.

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In (2) we may now neglect the ellipticity of the earth, putting R equal to a, the mean radius of the earth, and ϖ equal to $a \sin\theta$. Then

$$-\frac{gh}{4\omega^2 a^2}\frac{\partial}{\sin\theta\partial\theta}\left(\frac{\sin\theta}{\cos^2\theta}\frac{\partial P}{\partial\theta}\right)+P=Q; \quad . \quad . \quad (4)$$

or, with the notations

$$\frac{4\omega^2 a^2}{gh}=\beta \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and

$$\cos\theta=\mu, \quad . \quad . \quad . \quad . \quad (6)$$

$$\frac{d}{d\mu}\left(\frac{1-\mu^2}{\mu^2}\frac{dP}{d\mu}\right)-\beta P=-\beta Q. \quad . \quad . \quad . \quad (7)$$

For a given form of Q this equation can be solved by the methods applicable in tidal theory.[10] In the present problem the mean annual temperature at sea-level increases fairly regularly from both poles to the equator, and thus a rough representation of the conditions will be obtained by taking

$$Q=-k\mu^2 \quad . \quad . \quad . \quad . \quad (8)$$

where k is a positive constant. Then P will be an even function of μ. Further, with h equal to 7.3 km., and known values for the other quantities involved, we have

$$\beta=12.1 \quad . \quad . \quad . \quad . \quad (9)$$

In what follows the adopted value of this important number will be 12. To solve the equation, then, we follow the classical method and assume

$$\frac{1}{\mu^2}\frac{dP'}{d\mu}=A_1\mu+A_3\mu^3+A_5\mu^5+\ldots \quad . \quad . \quad (10)$$

whence

$$P'=B+\tfrac{1}{4}A_1\mu^4+\tfrac{1}{6}A_3\mu^6+\ldots\frac{A_{2n+1}}{2n+4}\mu^{2n+4}+\ldots \quad . \quad (11)$$

$$\frac{d}{d\mu}\frac{1-\mu^2}{\mu^2}\frac{dP'}{d\mu}=A_1+3(A_3-A_1)\mu^2+5(A_5-A_3)\mu^4+\ldots$$
$$+(2n+1)(A_{2n+1}-A_{2n-1})\mu^{2n}+\ldots \quad . \quad . \quad (12)$$

Equating coefficients,

$$A_1-\beta B=0 \quad . \quad . \quad . \quad . \quad (13)$$
$$3(A_3-A_1)=\beta k \quad . \quad . \quad . \quad . \quad (14)$$
$$5(A_5-A_3)-\tfrac{1}{4}\beta A_1=0 \quad . \quad . \quad . \quad (15)$$

and in general

$$(2n+1)(A_{2n+1}-A_{2n-1})-\frac{\beta}{2n}A_{2n-3}=0 \quad . \quad . \quad (16)$$

Put

$$N_{n+1}=\frac{A_{2n+1}}{A_{2n-1}} \quad . \quad . \quad . \quad . \quad (17)$$

Then by (16)

$$N_{n+1}-1=\frac{\beta}{2n(2n+1)}\frac{1}{N_n} \quad . \quad . \quad . \quad (18)$$

[10] Lamb, *Hydrodynamics*, 1924, §216.

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It is proved in works on tidal theory that the solution giving finite velocities at the poles satisfies

$$\lim_{n\to\infty} N_n = 0 \quad . \quad . \quad . \quad . \quad (19)$$

Hence

$$N_n = -\cfrac{\beta}{2n(2n+1) - N_{n+1}} = -\cfrac{\beta}{2n(2n+1) + \cfrac{\beta}{(2n+2)(2n+3) + \cfrac{\beta}{(2n+4)(2n+5) + \ldots}}} \quad (20)$$

which holds for values of $n \geqslant 2$. The resulting arithmetic gives

$$N_2 = -\frac{1}{2.08}\ ;\ N_3 = -\frac{1}{4.04}\ ;\ N_4 = -\frac{1}{6.51}\ ;\ N_5 = -\frac{1}{9.85}\ ;$$
$$N_6 = -\frac{1}{13.7}\ ;\ N_7 = -\frac{1}{18.3}\ ;\ N_8 = -\frac{1}{23} \quad . \quad (21)$$

Then (13), (14) and (15) give

$$A_1 = -\tfrac{1}{3}\beta k\,(1 - N_2) = -2.71\,k \quad . \quad . \quad (22)$$
$$B = A_1/\beta = -0.225\,k \quad . \quad . \quad . \quad (23)$$

Hence

$$\frac{1}{\mu^2}\frac{dP'}{d\mu} = -k\,(2.71\,\mu - 1.304\,\mu^3 + 0.323\,\mu^5 - 0.0496\,\mu^7 + 0.0050\,\mu^9 - 0.0004\,\mu^{11} \quad . \quad . \quad . \quad (24)$$

$$P' = -k\,(0.225 + 0.677\,\mu^4 - 0.217\,\mu^6 + 0.0404\,\mu^8 - 0.0050\,\mu^{10} + 0.0004\,\mu^{12} - \ldots) \quad . \quad . \quad . \quad . \quad (25)$$

But

$$hp'_s = P' - Q$$
$$= -k\,(0.225 - 1.0000\,\mu^2 + 0.677\,\mu^4 - \ldots) \quad . \quad . \quad (26)$$

The last result is easily checked by means of the formula

$$\int_0^1 p'_s\,d\mu = 0 \quad . \quad . \quad . \quad . \quad (27)$$

The numerical results are as follows:—

μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
$-10hp_{s1}/k$	2.25	2.15	1.86	1.40	0.81	0.14	−0.57	−1.26	−1.90	−2.43	−2.80

We notice that p'_s has a maximum at the poles, and diminishes steadily to a minimum at the equator. Accordingly there should be easterly prevailing winds at every part of the earth's surface.

To estimate Q, we may compare the results for England and the equator given by Dines in Table X. of the memoir quoted above. We have

$$Q = \int_0^{p_s}\int_0^{z} \frac{T'}{T_0}\,dp\,dz \quad . \quad . \quad . \quad (28)$$

and on comparing the values of this quantity for England and the equator we find after a numerical integration that the difference is 393 mb. km. The corresponding values of μ are 0.8 and 0. Thus k is about 600 mb. km., and the corresponding difference of pressure between the poles and the equator is, by the table,

$$\frac{5.05}{10}\frac{k}{h} = 41 \text{ mb.}$$

The velocities of the corresponding winds are of order

$$\frac{1}{2\omega a\cos\theta}\frac{\partial p'_s}{\rho\partial\theta} = 400\,\frac{\text{cm.}}{\text{sec.}}$$

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4. *The General Circulation (further discussion).*

The strength of the prevailing winds of the globe, inferred from the above theory, is in rough agreement with observational knowledge. But the occurrence of easterly winds everywhere is at variance with the facts. In the actual atmosphere there are belts of high pressure about latitude 30°, while the pressure diminishes systematically from these belts towards both poles, apart from irregularities attributable to the distribution of land. Between the belts of high pressure the prevailing winds are easterly; outside them they are westerly or south-westerly. The only neglected factor that could conceivably so alter the results is friction; and indeed it is easily seen that friction would prevent the persistence of such a motion as has just been investigated. For surface friction against a wind from the east is a force tending to push it back towards the east. Since we are considering velocities from west to east as positive, this amounts to increasing the angular momentum of the atmosphere. The process can stop only when the easterly winds at the surface have been annulled, or when westerly winds have been produced to such an extent that friction against them just balances the effect of friction against the easterly winds. The order of magnitude of the time needed for such a change is easily found. With surface winds of 4 m/s, the surface friction is about 0.5 dyne/cm.^{2}. The momentum of a column of air, 1 cm. in cross section, extending the whole height of the atmosphere, moving with velocity 4 m/s, is 4×10^5 gm. cm./sec. Thus the surface velocities would be annulled by friction in about 8×10^5 sec., or 10 days, if no other change occurred. Further, mere symmetrical heating would not regenerate them; it is inevitable that friction must on the whole push the atmosphere as much eastwards as westwards.

For the motion of the atmosphere to be steady, the angular momentum about the axis of the air between any two parallels of latitude must be steady. But the existence of any systematic general circulation implies by definition that the mean velocity is in much the same direction all round a parallel of latitude, and therefore that the surface friction on the air between two parallels is systematically either increasing or reducing its angular momentum. This effect must be balanced in some way to keep the motion steady. Ordinary viscosity is inadequate, and the only alternative is the interchange of air with other parts of the atmosphere; that is, convection (in the literal meaning of the term). Let us consider then the southward convection of angular momentum across a parallel of latitude. The distance from the axis is $\varpi + z \sin\theta$ for points in the same vertical line, and the angular momentum about the axis is therefore $\rho\,(\varpi + z\,\sin\theta)^2\,(\omega + \phi)$ per unit volume. The southward velocity being u, the southward flux of angular momentum across the whole parallel, at any height, is $2\pi \int_0^\infty \rho\,(\varpi + z\,\sin\theta)^3\,(\omega + \phi)\,u\,dz$. But the total mass north of the parallel considered cannot be varying systematically in one direction, and therefore

$$\int_0^\infty \rho\,(\varpi + z\,\sin\theta)\,u\,dz = 0 \quad . \quad . \quad . \quad (1)$$

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Let us write

$$\int_0^z \rho\,(\varpi + z\,\sin\theta)\,u\,dz = q \quad . \quad . \quad . \quad (2)$$

so that q is proportional to the rate of flow southwards at heights less than z. Evidently q vanishes when z is 0 or ∞. The southward flow of angular momentum is then

$$M = 2\pi \int (\varpi + z\,\sin\theta)^2\,(\omega + \dot{\phi})\,dq \quad . \quad . \quad . \quad (3)$$

taken through the atmosphere. Integrating by parts,

$$M = -2\pi \int_0^\infty q \frac{d}{dz}\{(\varpi + z\,\sin\theta)^2\,(\omega + \dot{\phi})\}\,dz$$

$$= -2\pi \int_0^\infty q \left[2\omega\,(\varpi + z\,\sin\theta)\,\sin\theta + v\,\sin\theta + (\varpi + z\,\sin\theta)\frac{dv}{dz}\right] dz \quad (4)$$

remembering that

$$(\varpi + z\,\sin\theta)\,\dot{\phi} = v \quad . \quad . \quad . \quad . \quad (5)$$

This equation is exact. Now we can put ϖ equal to $a\,\sin\theta$ with sufficient accuracy and neglect z in comparison with ϖ. Then

$$M = -2\pi a \int_0^\infty q\,\sin\theta \left(2\omega a\,\sin\theta + v + a\frac{dv}{dz}\right) dz \quad . \quad . \quad (6)$$

With actual values, the terms inside the bracket are respectively of order 4×10^4, 4×10^2, 4×10^5 cm./sec. The last is therefore very much the greatest. Thus approximately

$$M = -2\pi a \int_0^\infty q\,\sin\theta\,\frac{dv}{dz}\,dz \quad . \quad . \quad . \quad (7)$$

$$= 2\pi a\,\sin\theta \int_0^\infty \rho v a\,\sin\theta\,.\,u\,dz,$$

giving on integrating by parts again,

$$= 2\pi a^2\,\sin^2\theta \int_0^\infty \rho u v\,dz. \quad . \quad . \quad . \quad (8)$$

Let us now consider the moment of the frictional forces about the axis. The eastward frictional force per unit area is $-\kappa\rho_s v_s\,(v_s^2 + u_s^2)^{\frac{1}{2}}$, where κ is the coefficient of skin friction, about 0.002. Thus the eastward friction will produce forces on the air north of co-latitude θ, whose moment about the axis will be

$$-\int\int \kappa\rho_s v_s\,(v_s^2 + u_s^2)^{\frac{1}{2}}\,dS\,.\,a\,\sin\theta$$

$$= -\int_0^{2\pi} \int_0^\theta \kappa\rho_s a^3 v_s\,(v_s^2 + u_s^2)^{\frac{1}{2}}\,\sin^2\theta\,d\theta\,d\phi$$

$$= -2\pi a^3 \int_0^\theta \kappa\rho_s v_s\,(v_s^2 + u_s^2)^{\frac{1}{2}}\,\sin^2\theta\,d\theta \quad . \quad . \quad (9)$$

Here dS denotes an element of surface area. The air north of co-latitude θ is by hypothesis not gaining or losing angular momentum, so that the gain by friction must just equal the loss by

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convection to the south. The expressions (8) and (9) must therefore be equal. Hence

$$-\kappa a\int_0^\theta \rho_s v_s\,(v_s^2+u_s^2)^{\frac{1}{2}}\sin^2\theta d\theta=\sin^2\theta\int_0^\infty \rho uv dz. \quad . \qquad (10)$$

It is easy to see that this equation cannot be satisfied if the pressure distribution is symmetrical about the axis and the winds geostrophic, even with the usual modification near the surface needed to allow for friction. For u is in these conditions negligible except in the lowest kilometre, and there it is only about $\frac{1}{4}v$. Thus the ratio of the two sides is practically κa to a quarter of a kilometre, or 50 to 1. Allowance for the variation of $\sin\theta$ within the range of integration may reduce the ratio to 20 to 1, but in any case there is obviously a serious discrepancy. It is evident, therefore, that such wind velocities as actually occur at the earth's surface are incompatible with a steady symmetrical distribution of pressure. The maintenance of the polar circulation against friction requires a greater supply of angular momentum from without than can be provided merely by the drift of air across the isobars produced by surface friction.

Even if we abandon the restriction to symmetry, these considerations impose a severe restriction on the types of motion that are possible. The only change required is that u and v will involve ϕ, and the above argument leads to the equation

$$\kappa a\int_0^\theta \int_0^{2\pi}\rho_s v_s\,(v_s^2+u_s^2)^{\frac{1}{2}}\sin^2\theta d\theta d\phi=-\sin^2\theta\int_0^\infty\int_0^{2\pi}\rho uv dz d\phi \qquad (11)$$

instead of (10). If air moves to a large extent in directions deviating widely from the parallels of latitude, the products uv may become great enough to satisfy this equation.[11] But we notice that, in the northern hemisphere for instance, air moving northwards cannot proceed far without acquiring a velocity from the west, and air moving southwards acquires a velocity from the east. Considering any interchange of air across a parallel of latitude, then uv must be negative both for the air moving north and for that moving south. This corresponds to the observed preponderance of south-westerly and north-easterly winds over those in the other two quadrants. Hence the expression on the right of (11) is necessarily positive. But every factor in the expression on the left of (11) is positive except v_s. It follows that v_s is preponderatingly positive within the region considered. This result is independent of the temperature distribution. We have therefore the further result, which is easily seen to be applicable to both hemispheres, that if there is any circulation of air in polar regions at all, this circulation can be maintained against friction only by interchange of air with regions in lower latitudes; and that such interchange must always supply angular momentum in the positive sense to the polar regions, and therefore the circulation in polar regions must always be from west to east, whatever the temperature distribution may be. This is in agreement with what is observed in the southern hemisphere. The conditions in the northern hemisphere are more complicated on

[11] At this stage it becomes clear that ρuv has an intimate relation to the Reynolds shearing stress $\rho u'v'$.

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account of the large land masses, but the region of low pressure over Greenland,[12] in both summer and winter, may be considered confirmatory, especially as it is a cold region and would therefore be a region of high pressure on the simple thermal theory without allowance for friction.

Considering the matter quantitatively, we see that $\int_0^\infty \rho uv dz$ must be about 20 times as great as for a symmetrical system with similar resultant velocities. If u and v are comparable, instead of u being about $\frac{1}{4} v$ as was previously supposed, and if this remains true up to a height of about 5 km. instead of 1 km., the density being supposed uniform, the facts can be reconciled. Actually the density diminishes to some extent with height, and the height required will therefore need some increase to, say, 6 or 7 km. A further increase will be needed to allow for the fact that the correlation between u and v is incomplete, so that uv is on an average less than the product of the standard deviations of u and v. The polar circulation must therefore be maintained by streams of air whose depths are comparable with the height of the homogeneous atmosphere. The depth, indeed, appears to be so great that the north-easterly and south-westerly streams cannot exist one above the other; they must occur over different parts of the earth's surface. The surface wind, then, must blow from nearly opposite directions over different parts of the same parallel of latitude; but this implies a corresponding variation of pressure along a parallel of latitude.

Since the isobars must in any case be closed curves, this indicates a system of cyclones, whose heights must be comparable with those of the homogeneous atmosphere and the troposphere. This agrees with Dines's result that the pressure anomalies in temperate region cyclones extend up to the tropopause, but the constitution of the cyclone as fundamentally a combination of south-west and north-east winds appears to agree with the model of Bjerknes rather than with the symmetrical model of earlier writers; I think, however, that the apparent difference is one of emphasis and method of approach rather than of fact. On the other hand, the suggestions that cyclones represent either an instability of the general circulation, or oscillations about a steady general circulation, appear to be incorrect. These suggestions agree in assuming that a steady general circulation is possible; whereas it has been shown here that friction renders a steady general circulation impossible *ab initio*. Cyclones are then only the irregularities inevitable in any circulation when skin friction over the earth's surface is taken into account.[13]

The foregoing inferences rest on the postulate that there actually are prevailing winds on the earth's surface comparable with those inferred from the theory of a circulation without friction. This is a fact of observation, but it must be pointed out that the theoretical reason for it is far from obvious. Imagine first an atmosphere with all the level surfaces isothermal and isobaric, so

[12] *The Air and its Ways*, Pls. XX. and XXI.

[13] Exner, in the second edition of his *Dynamische Meteorologie*, pp. 216-7, suggests that cyclones are an essential component of the general circulation. His argument is quite different from that given here,

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that there are no winds at any height. Suppose now the temperatures adjusted very slowly until they reach their actual values, and then kept constant. The vertical expansion in the heated regions makes the pressure at a given height (other than zero) greater than in a cold region, on account of the extra mass of air above that height, and the pressure difference tends to push the air outwards. This tends to reduce the surface pressure in the heated regions and to increase it in the cooled regions, thus producing a system of easterly winds over the surface. Apart from friction, this process would ultimately produce a steady state, namely, that investigated in §3.2.

But when friction is taken into account it is evident, by what has been already shown, that the changes are not at an end at this stage. Surface friction can arise only when winds have been developed on the surface, so that it would produce little effect until a circulation had been established by the above process. But when a circulation exists the effect of friction is to make the air drift across the isobars towards the low-pressure side, thus tending to destroy any pressure differences that may exist. There is no obvious reason why the process should not continue until the whole surface of the earth is at uniform pressure, with no surface winds at all anywhere. The vertical distribution of temperature, however, would still depend on the latitude, and therefore there would still be winds in the upper air. The fact that we actually have winds on the ground indicates that such a state as this could not be permanent, and the reason for impermanence may probably be found in the variation of the wind over horizontal surfaces. This may well lead to horizontal eddies, or cyclones, giving rise to the horizontal Austausch of Defant,[14] but the mechanism is not clear. Friction will presumably tend to make the total energy a minimum, but this again, if the friction were small and proportional to the velocity, would generate the motion of 3.2. It would perhaps be more natural to try to make the total energy a minimum, subject to the additional condition that the surface velocities must be such that the total angular momentum is undergoing no secular change; but it is not easy to see how to apply such a method, since the energy of the cyclones themselves should appear in the total energy, and we lack a means of evaluating it.

In any case, however, there must either be surface winds or no surface winds when the air is subject to differential heating. The latter alternative is not in accordance with observation, though not for any evident dynamical reason. Taking into account, however, the observational fact that surface winds do exist, it has been proved by pure dynamical theory that the only possible motion consists of westerly circulations around the poles, with a corresponding easterly circulation in middle latitudes or near the equator (the difference probably depending on the temperature distribution) and with a system of cyclones closely similar to those we know. No steady general circulation of the atmosphere, without cyclones, is dynamically possible when friction is taken into account.

[14] *Geografiska Annaler*, 1921, pp. 209-265; *Met. Zs.*, **39**, 1922, 8-14.

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DISCUSSION.

Mr. L. F. RICHARDSON said that Dr. Jeffreys had discovered a very pretty analogy between a region in the atmosphere where the temperature was higher than normal, and a region on the sea where the equilibrium height of the surface was lower than normal on account of the attraction by the sun and moon. The analogy would be even prettier if equation (16) were multiplied through by some factor such as to make its terms of the same physical dimensions as the terms of the analogous equation (19).

Colonel E. GOLD said they were all very much indebted to Dr. Jeffreys for turning his powerful analysis to these meteorological problems. A paper like this would need time to study before one could discuss it adequately. One of the things which appealed most to him in it was on p. 100. It had always been one's idea that it was the anticyclones in the sub-tropical region which interfered with the regular trade winds, and that these anticyclones were due to the distribution of land and water. It was interesting to find from Dr. Jeffreys's analysis that it does not matter whether we have land and water or a uniform distribution of water over the whole globe, there will be no belt of SE or NE trade winds extending continuously around the earth. He would like to ask Dr. Jeffreys to explain why, in equation (6), p. 91, it is fair to cancel out a factor which is going to be zero. Another point was that Dr. Jeffreys says he is using the word "convection" in the literal sense of the word. We all of us think we do that, but he was afraid we did not always mean what he thought Dr. Jeffreys meant in his paper, that is, horizontal mass transference on a large scale, such as that involved in the trade wind systems. He thought it would economise speech to restrict the meaning of convection to transfer of heat by exchange of mass, the exchange proceeding in both directions simultaneously, and the currents involved being of small cross-section: they might be numerous and so extend over a wide area: they can certainly be horizontal as well as vertical. Perhaps Dr. Jeffreys meant that he used the word in the "lateral" sense. Dr. Jeffreys neglects the variation of g with height. That appears permissible in comparing pressure at a given level, but the variation of g with height affects the absolute pressure at 10 km. by half a millibar. Dr. Jeffreys did not make clear in his paper that he makes a due allowance for the variation of gravity over the surface of the globe. No doubt he does so implicitly, but it might be worth while making it explicit.

Mr. L. C. W. BONACINA said that in reading the paper one or two points had worried him greatly. Dr. Jeffreys throughout seemed to imply that the westerly circulation extended practically to the Poles with a definite centre of low pressure over the Poles, but observations showed that on the polar side of the 60th parallel in each hemisphere you again got prevailing east-wind. It is shown in the Antarctic and over the North Polar basin, the average pressure over the North Polar basin being not very much less than that in latitude 30°N. The low pressure belt is along the 60th parallel. In the accounts of various explorers in Greenland, such as Nansen, Peary, and De Quervain, it had been demonstrated that over the interior of Greenland there existed a glacial anticyclone, as a result of the overflowing winds and a very low temperature. The relatively high pressures over the North Polar basin, Greenland and the Antarctic, may be very shallow, but they do point to a surface temperature effect. It therefore seemed to him (Mr. Bonacina) that we must conclude that Dr. Jeffreys's results would

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apply to a uniform globe, that is to say, a globe divested of continentality, oceanity and glaciation. In that case Dr. Jeffreys's frictional cyclones would not bear much resemblance to our actual Bjerknesian systems, which depend upon contrasts of temperature which are themselves the effects of continentality, oceanity and glaciation: for if there existed an an entirely uniform globe, without continentality or monsoonal effects, the simple planetary circulation would be undisturbed, and winds changing latitude would quickly adjust their temperatures. Another point which struck him was that Dr. Jeffreys spoke repeatedly of the permanent belt of low pressure in polar regions. He would like to point out that the most intense anticyclones on the Earth's surface occur not in the region of high pressure in latitude 30°N, but in the low pressure belt, about 60°N, where there are frequently such intense cyclones. Even within the limits of Great Britain, this principle could be seen; for whereas in Scotland where very deep winter cyclones below 28.0 inches occur, there have been several instances of winter anticyclones over 31.0 inches; in England a sea-level pressure of 31 inches had never quite been recorded.

He felt that those points ought to be brought out, but the necessity for doing so did not lessen one's admiration of Dr. Jeffreys's masterly analysis.

Mr. C. S. Durst referred to Dr. Jeffreys's statement that from the analysis there was no obvious reason for the existence of surface winds, and asked if the release of energy due to condensation of water vapour in the equatorial belt might not be the explanation of their existence.

Dr. Jeffreys, in reply to Mr. Bonacina, said that the circulation near the North Pole was very irregular. It was probably much affected by the large glaciated land masses; if these were sufficiently important they could make air sweep across the pole to such an extent that the systematic circulation would be unnoticed. The outflowing winds over Greenland were not in themselves conclusive evidence of an anticyclone circulation; they might be antitriptic winds of small vertical and horizontal extent. Pilot balloon observations or accurate levelling across Greenland would be needed to decide the point. The argument from friction in the paper is independent of whether the globe is uniform or not; but in any case, if it is shown that a steady circulation is impossible on a uniform globe, it hardly seems likely that the imposition of irregularities on the surface would make one possible. There is no antagonism between this theory and the Bjerknes view of the structure of the cyclone; the theory, indeed, goes far towards explaining why the Bjerknes structure is necessary. The intense anticyclones in temperate latitudes spoken of by Mr. Bonacina are part of the irregularities shown to be essential, not of the mean distribution of pressure that gives the general circulation.

In reply to Colonel Gold's question about the cancelling of the frequency, Dr. Jeffreys said that in problems of tidal type without friction the analysis was always complicated by the possibility of free steady motions, which could not be said to be due to the disturbing forces. If the disturbing forces were first supposed to have a finite period, it could be definitely said that the periodic solution was due to the disturbing forces. If then the period is made indefinitely great this periodic solution tends to a definite limit, which can be said to be the motion due to the disturbing forces. If a direct attack was made on the problem of the effect of a steady distribution of temperature it would be impossible to separate the true effect of the temperature from the motion due to accidental initial conditions, but the device in the paper makes it possible.

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With regard to the meaning of "convection," Dr. Jeffreys thought it should cover all changes of the value of an element at a place due to the arrival of matter from somewhere else where that element is different. In meteorological literature it was often restricted to the effects of vertical motion, but those of horizontal motion were often as important though less spectacular. Often, again, it was used to denote the whole motion of the air, and not merely this particular type of effect produced by the motion. He himself confessed to having used it in a case where this effect was justifiably entirely neglected; but he considered that the sense first defined was far the most useful and satisfactory.

The allowance for the variation of g with height would be inappreciable. The motion arises from variations of temperature over the surfaces where $U + \frac{1}{2}\omega^2\varpi^2$ is constant, and the variation of g only enters multiplied by these small quantities.

With regard to Mr. Durst's inquiry, there was no difficulty about the amount of energy available; the energy in the frictionless motion considered was greater than in the actual motion. The problem was to explain how the energy attained its actual distribution in the atmosphere. The effects of humidity could be treated by a slight adjustment of the temperature.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 18, 1925.

At the *Ordinary Meeting* the following candidates were balloted for and elected Fellows of the Society:—

ERNEST GEORGE BEILBY, Inverleith, Matale, Ceylon;

JAKOB BJERKNES, D.Ph., Värvarslingen på Vestlandet, Bergen, Norway;

LANCE HAROLD BROWNING, Flight-Lieut., R.A.F., 3 (F.) Squadron, Upavon, Wilts;

EDGAR HAROLD BUTLER, 24, Westbury Road, New Southgate, N.11;

WILLIAM PATTERSON MCFERRAN, B.A., King Edward VI. Grammar School, Retford, Notts;

ALAN CAMERON MACINTYRE, 174, Papanui Road, Christchurch, N.Z.;

Mrs. IRIS MACLULICH, Haslemere Hotel, Montpelier Road, Brighton;

HAROLD VICTOR MICHELL, Flying Officer, R.A.F., Air Headquarters, Baghdad, Iraq;

Major MYLES HERBERT ROFFEY, University, Hong Kong;

HENRY TREVOR ROLLER, 42, Clanricarde Gardens, W.2; and

JOHN WARDALE, 35, St. George's Square, S.W.1.

Messrs. Ball, Baker, Ash & Co., Chartered Accountants, were appointed auditors of the Society's accounts for 1925.

December 16, 1925.

At an *Ordinary Meeting* the following candidate was balloted for and elected a Fellow of the Society:—

VICTOR DURY, King Edward VII. School, Taiping, Federated Malay States.

The PRESIDENT announced that a loyal Address had been forwarded in the name of the Fellows to His Majesty the King on the occasion of the death of Queen Alexandra, and a reply from the Secretary of State was read to the meeting.

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CORRESPONDENCE AND NOTES.

Weather Bureau, Manila.

Information has been received of the resignation, owing to ill-health, of the Rev. Father Algué from the Directorship of the Weather Bureau, Manila, Philippine Islands. The Rev. José Algué, S.J., was appointed Director in 1902, and was made an Honorary Member of the Royal Meteorological Society in 1906. He retires to the Colegio Maximo, Serria, Barcelona, Spain.

A Week of Fog.

Widespread and persistent fog characterized the weather of the Midlands, Northern England and Southern Scotland during the third week of November, 1925. In Liverpool the fog on Thursday and Friday, November 19 and 20, was described as the worst for thirty years. Shipping in the River Mersey was practically suspended, and similar conditions prevailed in the Humber and in the Firth of Forth. Accidents due to the exceptionally poor visibility were numerous both on land and sea. A steamer was stranded in the Firth of Forth and a railway accident occurred at Wincobank, five miles from Sheffield, while many minor mishaps were reported in the daily press. At Glasgow, where except for a few hours on Thursday evening when visibility lifted to between 1,000 and 2,000 yards, dense fog prevailed for a whole week and led to an exceptional dislocation of road and rail traffic. Both tram and omnibus services were brought to a standstill.

The history of the development of these unusually foggy conditions presents some very interesting features, especially as a complete series of records of upper air temperatures was made during the period.

On November 10, in the rear of a depression which moved eastwards to the continent, a flood of cold polar air invaded the whole country, and by the following day (November 11) anticyclonic conditions had become established over the British Isles, while a new series of depression commenced to move north-eastward across Iceland. Warm equatorial winds made their way northwards over the Atlantic to Iceland and the Faeroe Islands, the line of separation between these warm currents and the cold air over the British Isles curving from west towards east to the north of Scotland.

The mean 7 a.m. pressure distribution for the week November 16 to November 22 (both days inclusive) is shown in Fig. 1. On the whole, during the period in question the anticyclone was centred over N.E. England and the North Sea. Comparing these isobars with those of the normals for November, it will be seen that conditions showed a wide divergence from average, and little change occurred from day to day.

In the upper atmosphere temperatures, however, showed a progressive and decided rise. The low temperatures of the cold air supply which arrived on November 11 are well shown in Fig. 1 (curve 1), a reading of $-35°$ F. being recorded at 20,500 feet. Two days later, between 13,000 and 14,000 feet, the air was warmer by 24° F., and pronounced, but somewhat less marked heating of the upper layers occurred in the following days. Most, if not all, of this warming was presumably due to adiabatic heating by descent. No apparent change had occurred

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in the air supply over the country, judging by an examination of the daily weather charts. The polar front, apart from an undulatory motion, departed but little from its original position east to west to the north of Scotland, while from November 13 to November 19 the surface temperature at Duxford, where the ascents were made, was exceptionally constant. In the eight days the rise in temperature at 10,000 feet

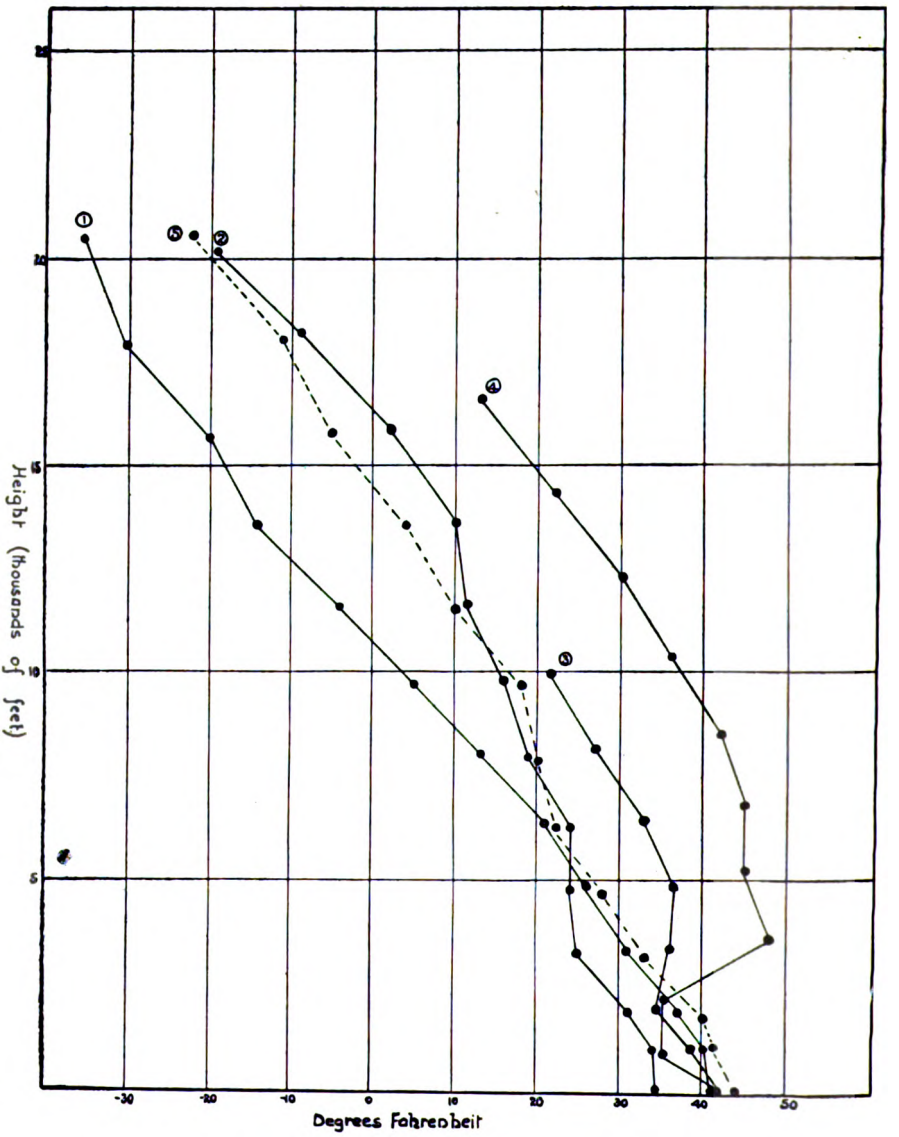

FIG. 1.—Upper Air Temperatures, Duxford.
1, Nov. 11, 18.00h.; 2, Nov. 13, 10.15h.; 3, Nov. 16, 14.30 h.; 4, Nov. 19, 10.00h.; 5, after passage of "cold" front.

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amounted to about 33° F., a heating which approximately corresponded to a descent of 6,000 feet, or, roughly, 750 feet per day. The warming in the middle layers was somewhat less marked, while the surface layers, unable to descend, remained at very nearly the same temperatures. This constancy of temperature in the ground levels, combined with the

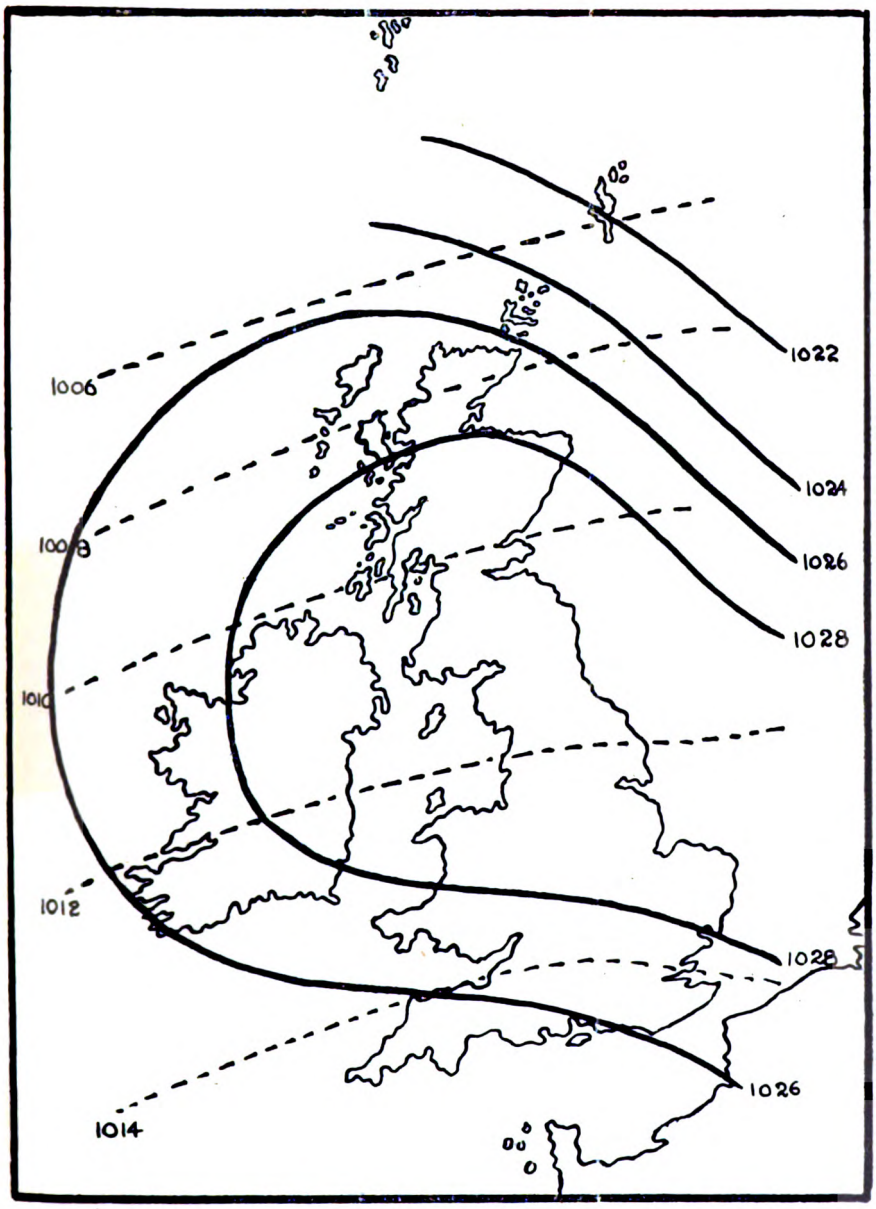

FIG. 2.—Average Pressure Distribution, Nov. 16-22 (continuous lines). Normal Pressure Distribution, November (pecked lines).

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decided warming above, gave rise to the well-marked inversion noticeable in Fig. 1 (curve 4). There were thus developed two of the chief essentials for the formation of fog-anticyclonic conditions and a stable ground layer. Only in the southern counties was the wind of sufficient strength to prevent a southward spreading of the fog area.

By November 19 the anticyclone, therefore, was no longer of the cold type and was thus only open to attack by means of a fresh influx of polar air, an attack which began two days later. The chart for 7 a.m. November 22 showed a depression near the Faeroes moving south-eastward to Scandinavia, and on Monday the polar currents in its rear had begun to push southwards over the British Isles. The anticyclone receded to the Atlantic and a pronounced drop in temperature occurred in the upper air (Fig. 1, curve 5). The passage of this cold front is, however, worthy of special notice in that, as will be seen by a comparison of curves 4 and 5, it led to rise in temperatures on the surface, the increase extending upwards to between 2,000 and 3,000 feet, and only above this layer did there occur a temperature decrease.

A Channel Snowstorm.

The experiences of two English pilots on the aerial route Croydon to Le Bourget on the morning of December 15, 1925, illustrate in a marked degree how, even with such a close network of reporting stations as is employed for the Civil Aviation Services, information of important weather phenomena may sometimes fail to come to hand, and incidentally how useful a close co-operation of pilot and meteorologist may prove to both parties.

The two pilots in question, leaving Lympne behind with a sky only half-covered with cloud at 2,500 feet, ran quickly into what proved to be an exceptionally heavy and continuous snowstorm. One pilot climbed to a height of 11,000 feet in an attempt to effect a passage, while the other attempted to pass beneath. Both efforts proving futile, a path either to the east or west was next tried, but this again proved unsuccessful and after two hours they were both forced to return to Lympne. The journey was later successfully accomplished at a height of 1,800 feet, one slight snow shower only being encountered.

The morning weather chart, at first sight, appeared to be quite innocuous and surface readings gave little clue to the cause of the phenomenon. Measurements of precipitation during the previous night had been slight in S.E. England, snow accounting for 0.5 mm. only at Hampstead, while a passing shower at St. Inglevert at 07.00 h. was the only report which approximated in the least degree to what was happening in the Channel. A secondary depression over Scotland was expected to move SSE and renew unsettled weather later, but, for the immediate future, prospects in SE England seemed fair.

Temperature differences, as far as surface observations were concerned, gave no indication of anything untoward, similar readings being recorded on both sides of the Channel. An examination of upper winds, however, showed that here lay a possible explanation.

Over England the wind, at 2,000-3,000 feet, was northerly in the coastal area, but further north, at Cranwell and Sealand, was from the north-west. On the continent, winds at the same levels came from the NE quadrant. These two currents converged in the Straits of Dover. This is well shown in the attached figure, which depicts for the

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layer 2,000 to 3,000 feet the lines of instantaneous air flow constructed from all available pilot balloon ascents. The crowding together in the Channel coincides with the position of the snowstorm, which was thus presumably due to the forced ascent of one or other of the two currents.

During the morning the amount of convergence decreased. The wind at Lympne fell off from 35 m.p.h. at 2,000 feet at 07.00 h. to 6 m.p.h. at 12.00 h., at which time the pilots were able to complete their journeys.

FIG. 1.—Lines of instantaneous air flow at 2,000 to 3,000 feet, Dec. 15, 1925.

Meteorological Observations at the Radcliffe Observatory, Oxford, 1925. (Communicated by the Radcliffe Observer).

Several changes in the routine of observation were introduced from the beginning of the year 1925. Eye-readings are now made at 9h. G.M.T. only, those which were formerly made at 12h. and 21h. having been discontinued. The photographic barograph and thermographs, which had been running continuously since 1880, have been dismantled, their places being taken by a large model Richard barograph and a Short and Mason thermograph. The readings with the solar radiation thermometer were discontinued from the beginning of the year. From May 1 observations of visibility have been made at 9h.

These changes have necessitated a presentation of the report on the weather conditions experienced at Oxford, which differs in a few details from the form in which it has hitherto been given.

The following were the chief characteristics of the weather at Oxford during the year 1925 :—

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The mean *Barometric Pressure* at 9h. G.M.T. (barometer reading reduced to 32°F. and mean gravity) was 29.730ins., which is 0.023in. below the mean for 70 years.

The mean *Maximum Temperature* of the air was 56°.7F. which is 0°.3 above the mean for 70 years. The mean *Minimum Temperature* of the air was 42°.3 which is 0°.2 below the mean for 70 years. The absolute maximum temperature, 84°.6, was recorded on July 22; and the absolute minimum, 19°.5, on December 6. The lowest grass minimum temperature, 11°.2, occurred on December 5.

The temperature of the air reached 80° on 8 days and fell as low as 32° on 53 days. The number of days of ground frosts (grass minimum as low as 30°.4) was 94.

The differences of the mean monthly temperatures (mean adjusted from maximum and minimum) from the corresponding means for 97 years are :—

	deg.		deg.		deg.
January	+3.0	May	+0.8	September ...	−3.1
February ...	+2.6	June	+1.4	October	+1.8
March	−1.1	July	+1.5	November ...	−3.2
April	−1.0	August	−0.2	December ...	−2.5

Wind. The total movement of the air recorded by the Robinson Anemographs with cups 116ft. above the ground was 77,292 miles, the records being reduced with the factor 2.2. The mean monthly velocities of the wind are given in the following table :—

	mi./hr.		mi./hr.		mi./hr.
January	10.76	May	8.99	September ...	8.42
February	12.33	June	6.54	October	7.98
March	9.42	July	7.35	November ...	8.22
April	9.04	August	6.84	December ...	10.22

The number of hours of *Bright Sunshine* amounted to 1,524, which is 46 hours above the mean for 44 years.

The monthly differences from the mean are shown in the following table :—

	Hours		Hours		Hours
January	+ 4	May	− 7	September ...	− 8
February	+ 7	June	+75	October	+ 2
March	−25	July	−13	November ...	+44
April	−10	August	−37	December	+14

Rainfall amounted to 26,621ins., being 0.429in. above the mean for 110 years. The number of " rain-days " (0.005in. or more) was 184.

The monthly differences from the mean were :—

	Inches.		Inches.		Inches.
January ...	−0.367	May	+0.689	September ...	+0.758
February ...	+1.794	June	−2.187	October ...	−0.049
March ...	−1.212	July	+1.333	November ...	−0.407
April	+0.406	August ...	−0.138	December ...	−0.191

Solar halos were observed on 150 days, parhelia being present on 31 days, and on 4 occasions parhelia were seen with no halo. The 46° halo was seen on February 6 (with parhelic circle and zenithal halo), 12, 13 (with zenithal halo), 14, 18, March 13, April 13 (with zenithal halo), and November 16. Contact arches were observed on 13 days. *Sun pillars* were seen on February 21, April 29, May 22, June 29, 30, October 23, and December 24.

Lunar halos were observed on 40 nights, being accompanied with paraselenæ, contact arch and 46° halo on February 7; and contact arch and 46° halo on December 24. A *moon pillar* was seen on March 10.

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The *Zodiacal light* was noted on 24 evenings (very bright on January 23), the zodiacal band on 8 evenings, and the counterglow on 5 evenings.

Two " records " were broken during the drought in the summer. June had the greatest number of hours of sunshine (267 hours) and the smallest rainfall (0.066in.) ever recorded here for this month.

Winter Thunderstorms in the British Isles.

Mr. S. Morris Bower, who is continuing his investigations of winter thunderstorms in these islands, has forwarded a preliminary summary of the results obtained for the three months January to March (inclusive), 1925.

Individual observers totalled 755 for England and Wales, 44 for Scotland, and 24 for Ireland.

Between January 1 and March 31, 1925, thunderstorms occurred on 57 days, a total exceeding that for the preceding year by nine days.

The following table shows the number of days during each month on which thunder or lightning was reported from each country.

TABLE I.—Days of Thunderstorms in the British Isles.

1925.	England & Wales.	Scotland.	Ireland.	British Isles.
	Days.	Days.	Days.	Days.
January... ...	10	12	10	17
February ...	20	10	8	20
March ...	16	5	4	17
Total for three months 1925	46	27	22	57
Total for three months 1924	35	22	11	48
Total for three months 1923	43	20	17	42

The number of days for both Scotland and Ireland is almost certainly too low on account of the comparatively small number of observers, and the scarcity of records from these two countries does not permit of an accurate distribution map being drawn.

In England and Wales the stormiest areas were the southern counties, particularly so in the case of the southern parts of Surrey and Sussex and the valleys of the Teign and Tamar. The areas free from storms embraced a belt stretching from East Yorkshire to SE Wiltshire and thence to the Bristol Channel, together with large areas in Wales and in the northern counties.

In January the storms of the 4th were the most noteworthy, reports being obtained from three distinct areas, viz., a large district round the Severn estuary and South Wales, a small area in the centre of west coast of Wales, and a well-defined area round Birmingham.

On February 14 storms were experienced all along the south coast from Plymouth to Brighton without, however, except in Devonshire, extending far inland.

On March 1 most of the south-eastern counties were affected, and on March 25 sharp local storms occurred in five widely separated districts.

Mr. Bower concludes an interesting summary, a brief account of which is given above, with an appeal for similar information for the months January to March, 1926. A note on a postcard giving time, duration and direction of the storm, an estimate of the storm's severity

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and whether accompanied by rain, hail or snow, the direction and strength of wind and changes of wind (if any), and finally, temperature changes (if any) during the storm, would be extremely useful.

Royal Observatory, Greenwich. Report to the Council of the Royal Meteorological Society for the Year 1925. (Communicated by the Astronomer-Royal.)

The ordinary meteorological observations have been continued as in previous years. Estimates of " visibility " at 9h., 15h. and 21h., according to the international scale, have been continued, and have been reported by telephone to the Air Ministry daily, together with the general weather report. Daily estimates of the intensity of ultra-violet radiation present in daylight have also been continued, and the results have been communicated weekly to the Medical Research Council at whose request the observations were undertaken.

During the year 1925 the temperature of the air varied between 89°.5F. on July 22 and 21°.4F. on December 5. On 22 days it rose to 80° or higher; and on 41 days it fell to 32° or lower. Of these 41 days, 21 occurred in the last two months of the year, namely, 10 in November and 11 in December, and 2 days occurred in April.

The mean temperature for the year was 49°.7, that is, the same as for the previous year and 0°.1 above the average for 75 years, 1841-1915. Considering the months individually, mention may be made of the unusual coolness of September. All but four days in this month were below the average for the time of year, and the average for the whole month was 3°.4 below the normal.

The highest reading of the solar radiation thermometer (black bulb *in vacuo*) was 173°.0—on two days in July, 2nd and 15th. This reading had not previously been reached at Greenwich. The lowest reading of the thermometer on the ground was 10°.4 on December 6. The extreme range exceeded 100°F. on no less than 87 days and the maximum range was 141°.9 on June 29.

The total number of hours of bright sunshine recorded during the year was 1,321. The maximum duration on any day in the year was on June 10 when 14.4 hours were recorded.

Although in general there was a deficiency of sunshine as compared with average totals (June and November providing the two exceptions), during the five months April to August inclusive, only six days in all were entirely sunless. The total number of sunless days in the year was 66.

An examination of the photographs taken during 1925 with the Night-sky Recorder, shows that the mean fraction of the total possible amount of clear sky at night recorded during the months December to April was 2.2 times as great as the corresponding fraction recorded by the sunshine recorder for the daytime. In the months May to November this ratio averaged 1.4. It may be remarked that the Night-sky Camera records the duration of clear sky at night over a small area at an elevation of 51° due north of the Observatory.

The total rainfall during the year amounted to 23.47ins.—a little below the average. March and June were very dry months. The rainfall in March was less than in any March since 1893, while that in June (0.12in.) was the lowest ever recorded for June, there being 24 consecutive days without rain. The month of July was wettest with 3.66ins. total rainfall,

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and also included the day of greatest rainfall for the year, namely, July 22, on which day 1.25ins. fell. No other day in the year had rainfall exceeding one inch, and only one other (Feb. 13) exceeded 0.75in. There were in all 162 days on which measurable rainfall occurred.

The remarkably low barometer reading of 28.39ins. was reached on the afternoon of December 20, and the reading remained below 29ins. for 75 consecutive hours during this depression.

The total horizontal movement of the air recorded by the Robinson Anemometer was 102,819 miles. The greatest daily movement was 791 miles on April 16 and the least was 33 miles on January 11. The greatest hourly velocity was 50 miles, between 10h. and 11h. on April 16. The greatest pressure recorded by the Osler Anemometer was 23.0lbs. to the square foot on January 1.

International Magnetic Character Figures.

A few words on the origin and significance of the international magnetic character figures may add to the usefulness of the table for 1923, which has recently appeared in the *Quarterly Journal*.[1]

A scheme has been in operation since 1906, whereby co-operating observatories—numbering at present about 40—send to the Royal Meteorological Institute of the Netherlands at De Bilt, their estimate of the magnetic character of each (Greenwich) day on the scale 0 (quiet), 1 (moderately disturbed), 2 (highly disturbed). The figures in Table II., p. 410, *l.c.*, represent the means of the daily character figures thus supplied by the different observatories. The principal object originally in view was the selection for each month of five magnetically quiet days. It had been a matter of general belief that the regular diurnal variation and the irregular changes, which when large constitute a magnetic storm, were independent. The regular diurnal variation was supposed to pursue a course decided by the local hour and the season of the year, but not by the presence or absence of disturbance. On this hypothesis, when determining the diurnal variation, it was desirable to avoid disturbed days, as disturbance obscured the regular phenomena. At some seasons the diurnal variation changes considerably in the course of a month. This made it desirable that the quiet time or times employed for the deduction of the diurnal variation should centre near the middle of the month. This object cannot always be secured by the employment of a single day, and five appeared the most suitable number of days for the purpose. By confining hourly measurements to the magnetograms of these five international quiet days—which commence at Greenwich midnight—a great economy of labour results, and mainly for this reason some observatories have derived diurnal variations from these days only. Others derive them also from all days, or from all but highly disturbed days. The difference between all day and quiet day diurnal variations is usually not large in lower latitudes, but is now known to be large in high latitudes. It is probably just as well that this was not generally known in 1906, otherwise the international scheme might not have come into existence, and our knowledge to-day might have been less than it is. Of late years the De Bilt authorities have selected five highly disturbed days a month, as well as five quiet days, and several stations, including Eskdalemuir, now publish diurnal inequalities for these disturbed days.

A quarterly sheet is issued from De Bilt which gives details of the

[1] Vol. 51, p. 410.

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character figures allotted to each day by each station. By those addicted to such pursuits as spotting the winner this sheet will be found quite fascinating, though its sporting possibilities have not yet been officially recognised. The results published in this *Journal* are taken from an annual publication, which appears some months after the end of the year. The daily character figures which it contains are useful for many purposes, but they do not give an *absolute* measure of anything. The principle on which the characters 0, 1, 2 are assigned varies with the station, or even with the change of a director. At some stations it expresses simply a general impression of less or more irregularity in the trace. At other stations the amplitude of the absolute daily range (absolute maximum less absolute minimum) serves as a criterion. But the absolute daily range is largely dependent on the regular diurnal variation, and in the quietest of times varies with the season of the year and with sun-spot frequency. The primary object set before himself by the average director of an observatory is to discriminate adequately between the days of the same month. This leads inevitably to character 1 implying less disturbance in a quiet than in a disturbed year. This general tendency influences the international figures, and should be remembered, especially when comparing mean monthly character figures from different years. On the other hand, meteorologists should remember that magnetic character is not a local phenomenon like pressure or temperature. This does not mean that on a particular day magnetic disturbance is equally large everywhere. On the contrary, it is almost invariably larger in high than in low latitudes. It is much larger, as a rule, at Lerwick, or even at Eskdalemuir, than it is in France or the South of England. But a day that has a high international character figure is highly disturbed all over the world, and a day with a low character figure is quiet everywhere, except, it may be, in really high latitudes. Thus magnetic character figures have an immediate application to world if not to cosmical problems. They have served to elucidate various matters, *e.g.*, the "27-day interval" existing in magnetic (and solar) conditions. Some illustrations of this from the 1923 table may interest those who are wanting an interlude to the pursuit of cross-word puzzles. The following is an example of disturbed days showing the 27-day interval, the international character figure being given in brackets: January 20 (1.1), February 25 (1.8), March 24 (1.9), April 20 (0.9), May 17 (1.6), June 13 (1.7), July 10 (1.4). In this case the disturbance extended on each occasion to at least two consecutive days. Thus we have January 30 (0.9), February 26 (1.6), March 25 (1.8), April 21 (1.2), May 18 (1.3), June 14 (1.2), and July 11 (0.9); all these 14 days except April 20 are international disturbed days. The interval is not an exact period like 27.0 days. For one thing, a magnetic disturbance lasts a considerable time, and has no recognisable centre. The apparent interval may thus be 26, 27 or 28 days. As an example of a quiet day sequence, we may take March 3 (0.2), March 30 (0.3), April 26 (0.1), May 23 (0.2), June 18 (0.1), July 15 (0.1), August 11 (0.1), September 7 (0.0), and October 4 (0.0). Here one step, May 23 to June 18, is only 26 days. In one case, October 24, November 20, December 17, we get repetitions of the rare character figure 0.0. Sequences such as these may owe something to man as well as to Nature, but that should enhance their general interest. For forecasting purposes they are risky, as they stop suddenly without warning.

The following table gives the international quiet and disturbed days of 1923:—

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TABLE I.—SELECTED MAGNETIC DAYS, 1923.

	Quiet Days.					Disturbed Days.				
January	7	8	18	19	27	13	20	21	29	30
February	9	12	13	21	23	17	25	26	27	28
March	8	9	10	11	23	15	24	25	26	27
April	2	5	17	26	27	12	13	21	22	23
May	1	12	13	22	24	3	17	18	29	30
June	9	10	17	18	24	4	13	14	21	30
July	5	14	15	21	24	7	10	11	18	23
August	1	18	21	28	29	3	4	6	13	24
September	7	8	16	21	22	9	10	26	27	28
October	2	3	23	24	30	15	16	17	18	19
November	5	10	15	20	25	2	12	22	27	29
December	2	7	17	21	22	23	24	25	26	27

There is a most undoubted connection of a general kind between terrestrial magnetism and sunspots. It is exhibited unmistakably only by the amplitude of the regular diurnal variation, which is invariably much larger (say 50 per cent. or more) at sunspot maximum than at sunspot minimum. The occurrence of exceptionally large magnetic storms at times when exceptionally large sunspots are central or nearly central on the solar disc, seems hardly attributable to pure accident, but active magnetic disturbance may occur without sunspots. For example, if we take the first sequence of seven disturbed days given above, four of them—February 25, May 17, June 13 and July 10—occurred at times when the sun was free of spots for several days (see Table III., p. 411, *l.c.*). While if we take the sequence of nine quiet days given above sunspots were present on six of them. C. CHREE.

Wolf's Sunspot Numbers.

The invention of the telescope led to the observation of sunspots in 1610, but their periodicity was not discovered until 200 years later. In 1843, Schwabe announced that his observations showed the existence of a period which he gave as about 10 years. For seventeen years he had counted the number of spots seen each day with two small refracting telescopes used with reduced apertures of $1\frac{3}{4}$ and 2 ins.; clusters of spots which seemed to be related he counted as units. His observations, commenced in 1826, were carried on for 40 years—through four maxima and three minima of the spot cycle—and showed clearly that the appearance of spots was periodic. He also noted as a corollary the number of spotless days year by year, and these numbers alone afforded proof of the reality of the period.

The discovery was due to Schwabe's regular and systematic plan of observation carried on for many years. There were several observers of the sun during the seventeenth and eighteenth centuries, who left on record their observations, such as those contained in Scheiner's *Rosa Ursina*, but none continued their observations sufficiently long to make them aware of any regularity underlying the apparent sporadic appearance of the sunspots.

Schwabe's discovery was extended in 1852 by the work of Dr. Rudolf Wolf, of Berne, and later of Zurich, who by a search into past records from various sources traced back the history of the spots to 1610, the time of Fabricius, Harriot, and Galileo. The data for the early cycles

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are very meagre, but they enabled Wolf to fix the epochs of successive maxima and minima. From 1749 onwards, he found, however, sufficient observations to give representative numbers for each month as well as for each year. The average period given by the collective observations was 11.12 years, a value which remains sensibly unaltered by the inclusion of other earlier data and over 50 years of later observations, rediscussed by several investigators. [1]

Wolf noted that this period was in near accordance with that announced by Lamont for the variation in the diurnal ranges of magnetic declination, a conclusion which was confirmed independently by Sabine, Gautier, and Ellis. He therefore examined early magnetic records and found that they thoroughly substantiated his sunspot numbers.

The observations of spots collected by Wolf were very heterogeneous in character, and in order to reduce them to a reasonable uniformity with one another and with regular observations carried on by himself and contemporary observers, he gave a representative number, or *Relativzahl*, for each month, based on the formula :—

$$r = k\,(f + 10g),$$

where g is the number of groups and single spots; f is the total number of spots which can be counted in these groups *plus* the number of single spots, and k is a factor depending upon the estimated efficiency of the observer and his telescope. Wolf took k as unity for himself, using a 3-inch refracting telescope with power 64. The monthly numbers (published by Wolf in No. 50 of his *Astronomische Mitteilungen*) from 1749 to 1876, were revised and extended by Prof. A. Wolfer, who succeeded Dr. Wolf at Zurich. These revised numbers up to 1901, both "observed" and "smoothed," may be found in the *Monthly Weather Review* for April, 1902, or the *Astronomische Mitteilungen* No. 93, and later values have been published annually in the latter publication from Zurich. For purposes of ready reference, it may be mentioned that the Jubilee Number of the *Astronomische Nachrichten*, gives Wolfer's collected numbers from 1902 to 1920, and the epochs of maxima and minima from 1610-1917. The *Meteorological Glossary* under "sunspot numbers," gives the yearly values from 1750.

As now published, Wolfer's spot numbers for month and year are derived from the collected observations of nearly forty observers in various countries, chiefly continental, and the daily record is practically unbroken by means of the co-operation of observers.

The spot numbers are admittedly arbitrary, and it is very satisfactory that they are found to represent closely the general solar activity as expressed by the more precise method of measurement of the areas of spots and faculæ. The mean daily areas of sunspots for each synodic rotation of the sun (about 27 days) from 1832 to 1900, have been collected by the Solar Physics Committee from the drawings of Schwabe and Carrington, covering the period 1832-1862, and from the Kew and Greenwich measures from photographs for the later years. The Greenwich measures of photographs taken at collaborating observatories are of nearly unbroken

[1] Wolfer from revised data gives 11.124 years (*Astronomische Mitteilungen* **93**, 1902, and *Monthly Weather Review*; April, 1902). Newcomb, 11.13 years (*Astrophysical Journal* **13**, 1901, 1). Schuster, 11.125 years with subsidiary periods of 8.63 years and 4.80 years. (*Phil. Trans.* **206**, 1906, 69). Turner, Greenwich data alone, 1876-1923, 11.50 years (*Monthly Notices Roy. Astron. Soc.* **85**, 471).

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continuity from 1874 onwards, and afford daily measures of spots both for position and area. Measures of areas of faculæ are also given.

Professor Schuster (*Phil. Trans.*, Vol. 206, 1906, p. 70) has derived a mean factor of 12.5 for converting Wolf's numbers into mean areas, corrected for foreshortening and expressed in millionths of the sun's hemisphere. For conversion of Wolf's numbers into *Greenwich* areas, corrected for foreshortening, a factor of 13.5, derived from a comparison of measures from 1874 to 1924, is rather more accurate. To convert Wolf's numbers into Greenwich *projected* areas, expressed in millionths of the sun's disc, the corresponding factor is 20. These are average factors only, for a comparison between the two methods of measuring sunspot activity shows that Wolf's numbers over-estimate in years of few spots and under-estimate in years of greater frequency, as compared with the spot areas. This is largely accounted for by the fact that when the sun is active, not only are the groups of spots more numerous, but the average size of the spots composing them is also greater than near minimum phase.

Although the measures of areas give a more accurate value of the state of the sun on any particular day, Wolf's and Wolfer's sunspot numbers are of great value for statistical purposes, as they give extremely good indications for the long interval from 1750 to the present day, and approximate values from 1610.

H. W. NEWTON.

Royal Observatory, Greenwich.

Wind Direction and Velocity and Day Horizontal Visibility at Cranwell, Lincolnshire, during the Period 1st April, 1920, to 30th September, 1925.

The object of the present note is to investigate the relationships existing between the ground horizontal day visibility at Cranwell, Lincolnshire, on the one hand, and (a) the surface wind direction and (b) the surface wind velocity, taken at the same time on the other.

The period over which the investigation extends is that from 1st April, 1920, to 30th September, 1925.

The observations utilized are those taken at the hours 0900-1700 G.M.T. (both hours inclusive). Some hours are missing owing to their occurrence on Sunday afternoons or on Bank Holiday afternoons, when observations were not taken.

All the wind readings are those measured by an anemobiagraph whose head is 43ft. above ground level at Cranwell, the station itself being 236ft. above sea-level.

The visibility observations throughout are divided into three groups: (a) those in which the visibility was 13 miles or more, termed in what follows "good or very good"; (b) those in which the visibility was 2¼ miles or more, but not reaching 13 miles, termed in what follows "indifferent or fair"; (c) those in which the visibility was less than 2¼ miles, termed in what follows "bad or poor."

The distribution of visibility with regard to wind direction, the wind being divided into nine groups, is shown in Table I. A certain number of observations were neglected owing to missing or faulty anemobiagraph readings.

Table I. shows that the highest percentages of "good or very good" visibility were obtained with winds from the two groups NE'N-ENE and S'E-SSW, whilst the lowest percentage of such visibility was obtained with

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the group SE'E-SSE. It also shows that the highest percentages of "bad or poor" visibility were obtained with the two groups SE'E-SSE and calm. The low percentages of "bad or poor" visibility with the three groups S'E-SSW, SW'S-WSW and NE'N-ENE are worthy of notice.

TABLE I.—THE DISTRIBUTION OF VISIBILITY WITH WIND DIRECTION.

Wind Direction.	Total Number of Observations.	Percentage of such Observations Visibility was		
		Good or Very Good.	Indifferent or Fair.	Bad or Poor.
N'W-NNE	1266	24.5	65.8	9.7
NE'N-ENE	1541	38.1	55.1	6.8
E'N-ESE	1265	25.8	58.2	16.0
SE'E-SSE.	1441	15.4	58.5	26.1
S'E-SSW	2098	34.8	58.7	6.5
SW'S-WSW	3555	26.6	66.9	6.5
W'S-WNW	2004	22.1	68.2	9.7
NW'W-NNW	2253	29.6	59.8	10.6
Calm.	270	22.6	55.9	21.5

The distribution of visibility with regard to wind velocity, the wind being divided into five velocity groups, is shown in Table II. Once more a certain number of observations were neglected owing to missing or faulty anemobiagraph readings. It is to be noted that the numbers neglected under the headings of this paragraph and of paragraph three are not the same, as on some occasions only the velocity given by the anemobiagraph was in error and in others only the direction, whilst in some cases both velocity and direction were lacking or in error.

TABLE II.—THE DISTRIBUTION OF VISIBILITY WITH WIND VELOCITY.

Wind Velocity. mi./hr.	Total Number of Observations.	Percentage of such Observations Visibility was		
		Good or Very Good.	Indifferent or Fair.	Bad or Poor.
0-5	2724	17.7	59.2	23.1
6-10	3708	17.6	63.8	18.6
11-15	4005	25.8	65.9	8.3
16-20	3344	30.8	66.1	3.1
Over 20	1951	48.5	49.9	1.6

Table II. shows that considering winds greater than 15 m.p.h., such winds are seldom accompanied by "bad or poor" visibility, but are in fact accompanied by a large percentage of "good or very good" visibility.

WILLIAM H. PICK.

Cranwell, Lincolnshire,
December 7, 1925.

Note on Halo Frequency and the Succeeding Occurrence of Precipitation in London, 1918-1924.

Popularly, a fairly widespread belief is existent as to halos being the forerunners of precipitation, and references to this association are also to be met with both in proverb and poetry.

During the years 1918-1924, a record has been kept of the appearance

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of solar and lunar halos in London, and whilst some of short duration have probably been missed an endeavour has been made to obtain as complete a record as possible.

Probably the most complete record of halo phenomena in the British Isles is that kept at the Radcliffe Observatory, Oxford. During the years 1918-1924 the annual average number of solar halos at Oxford was 128 compared with 105 in London, and for lunar halos 39 as against 35.

No record as to size has been kept, but the 22° halo is by far the most common, followed by the 46° halo, and least common of all the 90° halo.

By far the larger number of solar halos show a prismatic effect, lunar halos very infrequently.

Table I. shows that solar halos are most frequent from March to June, and that one winter month, December, also has a high frequency. Lunar halos are most frequent in winter with a mean number of 5.6 for December, and least frequent from May to September. The disparity between the number of lunar and solar halos is partly to be accounted for by the shortness of the summer night, and also by the age of the moon, which, as a general rule, must be between first and last quarter in order to yield sufficient light for the production of a halo.

TABLE I.—THE NUMBER OF HALOS OBSERVED IN LONDON, 1918-1924, INCLUSIVE.

SOLAR HALOS.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1918	3	3	5	3	4	9	7	10	5	6	4	5	64
1919	5	3	9	10	8	10	6	6	6	6	9	13	91
1920	10	5	13	10	8	12	10	5	11	6	10	8	108
1921	9	4	13	7	8	9	8	9	9	12	8	13	109
1922	10	10	10	17	12	7	9	9	6	8	7	15	120
1923	9	9	11	8	16	13	11	14	11	13	11	8	134
1924	8	6	10	11	11	12	10	11	8	7	8	8	110
Mean	7.7	5.6	10.1	9.4	9.6	10.3	8.7	9.1	8.0	8.3	8.1	10.0	

LUNAR HALOS.

1918	2	2	1	2	0	0	0	0	2	0	2	4	15
1919	4	2	4	3	1	1	1	3	0	5	2	9	35
1920	6	5	6	6	2	0	0	0	0	3	3	7	38
1921	6	2	3	4	1	1	2	0	0	4	2	7	32
1922	5	5	4	2	5	1	3	3	0	3	6	8	45
1923	6	3	7	9	1	1	1	1	1	7	4	3	44
1924	6	3	3	5	1	5	1	2	3	1	0	2	32
Mean	5.0	3.1	4.0	4.4	1.6	1.3	1.1	1.3	0.9	3.3	2.7	5.6	

Solar halos occur in every individual month of the period under consideration, the number being as low as three in several months, and as high as 17 in March, 1922.

Lunar halos are not observed in every month, though as many as nine were seen in December, 1919, and April, 1923.

Extreme variations occur in the duration of halos, from a few minutes to many hours. Cases have occurred where a solar halo has prevailed persistently from sunrise to sunset, and a lunar halo in the early evening has still been visible the next morning.

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Table II. is a summary showing the relation of halos to precipitation within 12 or 24 hours from the appearance of the halo.

TABLE II.—Monthly Halo Frequency and the Occurrence of Precipitation in London, 1918-1924.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total and Means
SOLAR HALOS.													
Total number considered	54	40	71	66	67	72	61	64	56	58	57	70	736
Proportion followed by precipitation within 12 hours (per cent.)	61.1	52.5	53.5	51.5	58.2	41.7	50.6	51.5	51.8	53.5	43.9	57.1	52.7
Proportion followed by precipitation within 24 hours (per cent.)	81.5	65.0	74.7	72.7	68.6	54.2	72.1	68.7	69.6	72.4	71.9	84.3	71.3
LUNAR HALOS.													
Total number considered	35	22	28	31	11	9	8	9	6	23	19	40	241
Proportion followed by precipitation within 12 hours (per cent.)	60 0	40.9	46.2	54.8	0.00	33.3	50.0	55.5	16.7	56.5	68.4	72.5	46.2
Proportion followed by precipitation within 24 hours (per cent.)	71.4	50.0	67.8	77.4	18.2	55.5	75 0	55.5	50 0	65.2	68.4	82.5	61.4

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Considering solar halos, it is apparent, that with the exception of the months of June and November, more than 50% are followed by precipitation within 12 hours. Extending the period to 24 hours, excepting February and June, precipitation follows in approximately 70% of the cases, being as high as 84% in December, and 81% in January. Although the number of lunar halos dealt with is relatively small the results are not very dissimilar.

SPENCER RUSSELL.

OBITUARY.

MR. J. Y. BUCHANAN, M.A., F.R.S.

We regret to announce the death, in London, suddenly on October 16, 1925, of Mr. John Young Buchanan, M.A., F.R.S.

Born at Dowanhill on February 20, 1844, he was educated at Glasgow High School and at Glasgow University. He studied later at Marburg, Leipzic, Bonn, and also in Paris at the Ecole de Médicine, and it was at these places he acquired his marvellous facility in foreign languages.

He made his first reputation as chemist and physicist to the "Challenger" expedition of 1872-1874. It was on this voyage that he demonstrated that *Bathybius*, which Huxley had believed to be the most primitive form of life, was merely a gelatinous form of calcium sulphate thrown down by the alcohol used in the preservation of specimens.

On his return, Buchanan established private laboratories, both in London and in Edinburgh. He was gifted not only as a chemist, but as a mineralogist, and made annual visits to Switzerland for the purpose of studying snow and ice problems. His most important papers were published under the title of "Comptes Rendus: Observation and Reasoning."

He was awarded the Keith medal of the Royal Society of Edinburgh and the gold medal of the Royal Scottish Geographical Society. In 1887 he was elected to the Royal Society, and he served as vice-president of the Oceanographic Institute established in Paris by the late Prince of Monaco.

He was a charming and stimulating companion and took a generous pleasure in helping those less endowed with this world's goods.

He was elected a Fellow of this Society in 1901 and served as a Councillor for the years 1903-4.

SIR WILLIAM SCHLICH, K.C.I.E., F.R.S.

We regret to announce the death at his residence in Oxford on September 28, 1925, of Sir William Schlich, K.C.I.E., F.R.S., at the age of eighty-five.

Born in Germany on February 28, 1840, he brought to the country of his adoption an instructed enthusiasm for forestry, which largely by his labours has been raised to its present position in the British Empire. Educated at Giessen University, he later accepted an appointment in the Indian Forest Department, promotion following quickly. He became, in 1872, Conservator of the Province of Bengal, and in 1881 he succeeded Dr. Brandis as Inspector-General of Forests, a post he held until 1885, when he was transplanted to England to organize the first School of

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Forestry at Coopers Hill. Here he remained for twenty years, and in 1905, when the school was transferred to Oxford, it was to Schlich that the task fell of dovetailing a new study into the existing arrangements of the University.

Retiring from the Civil Service in 1911, he was appointed Reader at the University and given by special decree the status of Professor of Forestry.

He was elected to the Royal Society in 1901, and in 1909, having been naturalized while at Coopers Hill, was created K.C.I.E.

His publications include among others "A Manual of Forestry" and "Afforestation in Great Britain and Ireland." He was elected Fellow of this Society in 1886.

Mr. G. L. Smith.

We regret to announce the death at York House, Chertsey, on September 25, 1925, of Mr. George Lawrence Smith, the head of the instrument design and research department of the Royal Aircraft Establishment.

Born about 1870 at Aberdeen, he followed various pursuits of a scientific nature, and on the outbreak of war in 1914, he offered his services to the Aircraft Establishment as an ordinary draughtsman. His ability soon earned promotion.

He took a keen interest in meteorology and did work of considerable interest in the design of a meteorograph for use in unmanned kite balloons and also in developing a method of measuring turbulence of the atmosphere by means of aeroplanes. He was elected a Fellow of this Society in 1919.

Mrs. M. Wilkin.

We regret to announce the death, on October 23, 1925, of Mrs. Mary Wilkin, of "Summerhill," Smallhythe, Tenterden, Kent, in her ninetieth year.

The widow of the Rev. A. Wilkin, she took a great interest in the affairs of the district and ministered largely to the welfare of the inhabitants, besides making generous gifts towards the upkeep and refurnishing of the church.

She was elected a Fellow of this Society in 1907.

REVIEWS.

Etude sur le climat de la Grèce. Précipitation. Stabilité du climat depuis les temps historiques. Par E. G. Mariolopoulos. Paris (Les Presses Universitaires de France), 1925. 8vo. Pp. 66.

The first part of this paper is a useful statistical account of the seasonal and annual distribution of rainfall over peninsular Greece, illustrated by five maps of isohyets. Unfortunately, the periods covered by the different records are not stated. The frequencies of rain, snow, hail and thunderstorms are also tabulated, and a list of the heaviest falls in 24 hours is given. Several of these exceed 150 mm., but the impressive total of 2,050 mm. in a day at Corfu, which heads the list, is presumably a misprint. The variable and uncertain character of the rainfall is shown by a table of annual totals. The second part deals with the vexed question of climatic changes. The author refuses to

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admit that there have been any such changes, and supports his contentions with a series of quotations from classical authors. He demonstrates that we have no good reason for supposing that the climate of the first half of the third century B.C. differed appreciably from the present climate of Greece, but one of his quotations shows that changes of climate were an acute question even in classical times. Plato at least believed that Greece was becoming less fertile, though he attributed the change rather to the washing-away of soil than to a decrease of rainfall. Krause's comparison between the accounts of two islands given by Homer and by Aristotle, which seems to indicate a change of climate, is not referred to.

C. E. P. B.

(1) *Civilisation and Climate.* By ELLSWORTH HUNTINGTON. Third edition, revised and rewritten, with many new chapters. Pp. xix + 453. (New Haven: Yale University Press; London: Oxford University Press, 1924). 23s. net.

(2) *Principles of Human Geography.* By ELLSWORTH HUNTINGTON and SUMNER W. CUSHING (Huntington Geography Series). Third edition, revised. Pp. xviii + 430. (New York: J. Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1924). 15s. net.

(1) It is a welcome sign of general interest in meteorology and its applications to human problems that *Civilisation and Climate* has reached a third edition. The book was first published in 1916, and was reviewed in the *Quarterly Journal* for 1917, p. 104, when the criticism was brought that the basis of the argument, consisting mainly of studies of the amount of work done by factory operatives and others in the eastern part of the United States under various weather conditions, was not broad enough for the theoretical edifice which was erected upon it. This objection does not apply with the same force to the present edition, in which the basis has been materially strengthened by the inclusion of a number of studies of the death rate under different weather conditions in various parts of the world. These studies strengthen the author's original conclusion that the variable climate of the temperate storm belt, typified by the north-eastern part of the United States and by Great Britain, is the most favourable in the world for human health and progress. The characteristic features of this temperate storm climate are favourable mean temperature, appreciable annual range, and frequent passage of depressions, and by assigning numerical values to each of these factors the author estimates the comparative "energy value" of other climates and prepares a chart of "climatic energy." He also constructs a chart of "civilisation," based on an international consensus of opinion, and the two charts of "climatic energy" and "civilisation" show remarkably close agreement.

In the last chapters of the book the theory of "climatic energy," in conjunction with the author's well-known views about climatic cycles, is applied to account for the locations of the great civilisations of antiquity in regions whose inhabitants are at present extremely backward. This theory is of great interest, but the knowledge of climatic changes gained during the eight years which have elapsed since the appearance of the first edition, seems to have added to the objections against it rather than to have made its acceptance easier.

(2) *The Principles of Human Geography* is a text book in which the control of human energy and progress by climate is systematically, and for the most part successfully, employed as a guiding principle in describing the organisation of human society in all parts of the world. Humanity may be divided into three grades; in the lowest, man is

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dominated by his environment; in the second, he is able to utilise the advantages and to some extent overcome the disadvantages of his environment. The highest grade is formed by "cyclonic" man, who might almost be said to create his own environment, reaching out to the ends of the earth for all that he requires. The first edition of this book appeared in 1921 (reviewed in the *Quarterly Journal* for 1922, p. 83), and its success is shown by the fact that three editions have appeared in four years. C. E. P. B.

Peut-on Prédire le Temps? By JEAN MASCART. Lyon (Audin et Cie), 1924. 4°. Pp. 74.

The genial pessimist is a good companion; he provides a salutary check on our wilder enthusiasms and we can count on a quiet sympathy for our tale of failure. A pessimist become hilarious jars on every mood. Thus we must describe the author of this essay and its effect.

Most of us have at some time been irritated by the question "Well, what weather is that a sign of?" M. Mascart is a seeker after signs. He asks for signs and a mechanical method of forecasting therefrom. The order in which he considers his signs and methods is an interesting study in demoralisation. He starts with a depression and extrapolates its known path. This is not infallible; therefore the movements of depressions are capricious! From this he descends through other mechanical methods of forecasting to a bird which sings in a particularly plaintive manner when it is going to rain. The bird, however, is of a migratory species, and thus fails the forecaster for several months of the year! (It is not in any place easy to know if M. Mascart carries his hand on his heart or his tongue in his cheek.)

"New methods called Norwegian" are referred to in a footnote. These to the author are probably more "signs," but he is evidently very sceptical as to their success. Throughout the essay, there is no evidence of the author having any conception that Meteorology is simply the application of well-known physical laws to the very complicated case of the atmosphere.

Figures showing the percentage success of forecasts lend themselves to sarcastic treatment, and M. Mascart makes the most of his opportunity.

We are given a grain of encouragement towards the end. Certainly we cannot hope to know to-morrow's weather, but with care and perseverance we can know and put on record a little about the present weather.

The essay is not very long, and so is perhaps worth reading. Parts are humorous and there are veiled and tantalizing allusions to French political matters. A good slang dictionary will be useful.

R. A. W.

Notes sur la variabilité des climats. Documents lyonnais, études de climatologie. Première partie. Introduction générale historique. By JEAN MASCART. Lyon (Audin et Cie) [1925]. 8°. Pp. 383. 25fr.

This long essay is a preface to some detailed climatological studies, which the author proposes to publish shortly. It is a critical review of the work which has been done on the variability of climates—and "climate" includes magnetic and electrical phenomena, earthquakes, volcanoes, the distribution of land and sea and living creatures! The author begins by regretting the passing away, a century ago, of the encyclopaedists.

The bibliography occupies sixty-two pages and more than 1,000 authors are cited. Most of these earn a few words of criticism in the text, yet the final result is a connected essay and not merely a series of abstracts. None will read it without being led along some curious and interesting byways of meteorological literature, but to gain these he must

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cross many old battlefields—wearisome desolated areas littered with still harmful theories of non-existent periodicities.

To criticise such a production except in trivial details is difficult, to summarise its contents impossible. It is itself a summary and its 62-page bibliography is its table of contents. The author comes to no conclusions except that our knowledge of the facts of the variations of climates, the variations of yesterday as well as the variations of the last glacial period, is altogether inadequate. He puts forward a plea for the collection of precise and homogeneous data, a thing he fears made more difficult through the control of official meteorology by the military services, who are of necessity most interested in day to day forecasting. A useful book to possess for reference, but rather wearying to read through all at once.

R. A. W.

Cloud Studies. By ARTHUR W. CLAYDEN, formerly Principal of University College, Exeter. Second edition, revised. London (John Murray), 1925. 8°. Pp. 15 + 200, pls. 64. 15s. net.

No one who reads this book by Mr. Clayden can fail to perceive that he has made a very complete study of his subject and that he is deeply interested in it. This is also apparent from the date of a reference he gives to one of his own papers on the "Thickness of Shower Clouds," which he read before the Meteorological Society nearly forty years ago. His opinions on the subject are therefore of great value and not to be lightly criticized.

There are sixty-four illustrations, mostly cloud photographs taken by the author, each of which denotes a type of cloud to which a definite name is given. Mr. Clayden disclaims all intention of superseding the nomenclature of the *International Cloud Atlas*, but says that those who make a close study of the subject require a much finer definition than the *Atlas* affords. He is well aware of the tendency of typical cloud forms to merge almost imperceptibly one into another, and compares his process to the difficulty of selecting types of the links of a chain in which each link is almost exactly like its neighbour, "yet no two are alike, and the greater the distance between them, the less the likeness."

The first edition was issued in 1903, and in the preface to the present edition the author states that so much knowledge of the physical processes of the atmosphere has accumulated since that date, that some of the conclusions reached as to the formation of clouds require modification. The state of our present knowledge on the subject is very fairly set out in Chapter II. Mr. Clayden admits that much still remains unknown.

There is one point in which fault is found with the international nomenclature, justly in the opinion of the reviewer, and that is in the use of the word "nimbus" for denoting a special type of cloud. As the author shows, rain falls from nearly all types of clouds, and what is called nimbus is often merely the bottom of a layer of some other type. Mr. Clayden's comment is that the word nimbus should be used as an adjective and not as a substantive.

The illustrations are very good, especially those relating to cirrus in its various forms and compounds. The only ones to which the reviewer is inclined to take exception are two photographs of strato-cumulus. These represent the type as clouds having well-defined and sharp edges, but the usual appearance of strato-cumulus is a formless and indefinite sort of cloud, to which Clement Ley assigned the term "dreary." It is very common, at least in the south-east of England, especially in winter, during anticyclonic weather, and is a fine weather type of cloud at all seasons. Much experience in kite flying has shown the reviewer that it nearly always lies just under a sharp inversion of temperature.

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The last two chapters of the book describe the photographic process used by the author in obtaining the photographs and his method of finding the height of the clouds. Two photographs are taken of the same cloud from the end of a base line of convenient length at a time when it is possible to get an image of the sun and cloud on the same plate. The shutters of both cameras are actuated by the same electric current, so that the photographs are actually simultaneous. The exact time being noted, the precise azimuth and altitude of the sun can be calculated and they give a known point of reference on each plate. Mr. Clayden uses a base line of 200 yards length running east and west, and he finds this too long for low clouds and too short for high clouds, but as his cameras are fixed, he has to choose once for all the length that is most generally convenient. There are obvious objections to the method, as indeed there are to most other methods, but it seems in his hands to have yielded very satisfactory results. The book can be thoroughly recommended both to the meteorologist and to the general reader.

W. H. DINES.

Memoirs of the Royal Meteorological Society.

The Council propose that papers involving highly technical methods of description shall in future be published in a series entitled *Memoirs of the Royal Meteorological Society*.

The Council would have desired to print in the new series the paper by Sir Gilbert Walker and E. W. Bliss appearing on p. 73 of this issue of the *Journal* and also that by Harold Jeffreys appearing on p. 85 had the arrangement for the issue of the *Memoirs* been completed on the dates of reading.

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QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

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THE ACTIVITIES OF THE ROYAL METEOROLOGICAL SOCIETY.

By Mr. C. J. P. CAVE, M.A., J.P., President.

(An address delivered before the Royal Meteorological Society, January 20, 1926.)

In reviewing the activities of the Society during the past year I should like especially to mention the Seventy-Fifth Anniversary of the foundation of the Society. Some might think that it is fitting to celebrate the 50th or 100th anniversary of a society, but that a seventy-fifth is hardly necessary, but 25 years is a very good unit of time in the life of a society, and in the case of our Society the advances made in our science in the past quarter of a century are such as to render a special celebration particularly appropriate. I think that everyone who attended the celebrations will agree that the functions were of distinct advantage to the Society. Many Fellows who seldom attend the ordinary meetings came to some of these special meetings, and this was especially the case with the meeting at Kew Observatory, and we feel very grateful to the Director of the Meteorological Office for inviting us to the Observatory. In another way the celebrations were of a distinct advantage. In these days science is international and it is of importance for a scientific society to keep in touch with foreign countries. We were fortunate in the fact that the Upper Air Commission was meeting in London last April and that we were able to welcome a number of foreign meteorologists at our meetings, and to have had the privilege of hearing a lecture from Prof. van Everdingen. Later in the year we were also able to welcome Dr. C. G. Abbot, who gave us an address on his latest work on solar radiation. As you will see in the report of Council we have elected eight new honorary members, foreign meteorologists of the first rank; so that in many ways we have been in touch with other countries where our science is being studied.

Perhaps the most important thing that has occurred in the Society in the past year is the reorganisation of the *Journal*. As I mentioned in my last year's address the question of the *Journal* is a difficult one. We have to keep up to date in our publications, and in consequence we have to publish a good many papers which are rather hard for the average Fellow to understand. I am not casting any aspersion on the average Fellow; I admit frankly that many of the papers that have been published in the *Journal* are not of a kind that I can understand, even with the most careful reading.

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We should rejoice that this is so; it shows that we have a number of Fellows who are able mathematicians, and that our *Journal* has such a high standard that they are glad to put forward their views in our pages. But there is another side to the question; the majority of our Fellows, many of whom live far from London, and some far from England, find, as I do, that the *Journal* is sometimes rather stiff reading, and the *Journal* is all they get in return for their support of the Society. Well, I hope that all these difficulties have been overcome. We have had a gift from several Fellows of the Society, which is to be continued for five years, towards the expenses of the *Journal*, in order to make it more interesting to the average Fellow. We have had also a grant of £150 through the Royal Society from the Government Publication Grant to assist us in the publication of papers of a highly technical nature, and have been able in consequence to arrange that the Society should have two separate publications; firstly, the *Quarterly Journal*, which we hope may become of far greater interest than it has been to Fellows who cannot follow advanced mathematics; and secondly, a series of *Memoirs* which will contain papers of a highly technical nature. A copy of the first published memoirs will be sent to all fellows, but afterwards they will only be sent to those fellows who ask for them. In this way I hope that we shall be able to give all Fellows interesting reading in our publications, and that the scientific standard of what we publish will be, if anything, increased.

In coming to the fellowship of the Society, we may congratulate one of our Fellows, Dr. Jeffreys, on becoming a Fellow of the Royal Society; Mr. W. W. Butler on receiving a baronetcy, and Prof. T. Hudson Beare a knighthood in the recent birthday Honours. I am sorry to say that the number of deaths has been very high; the number is 24 and has, I believe, never been equalled. Two of our honorary members, too, have died, Professor Hildebrandsson and Dr. Ekholm, both of Sweden. Professor Hildebrandsson's name is known to all meteorologists. Until quite recently he was taking an active interest in meteorology and, despite his advanced age of 87, had lately issued several publications.

I must also specially mention Captain Carpenter, a Fellow for over 45 years, and who formerly served on the Council and took an active part in the affairs of the Society. He served on the Challenger expedition.

You will remember that last year I showed you a graph of the membership of our Society. I again show you this slide brought up to date; I am sorry to say that the drop in membership noted last year has not only continued but has been accentuated. This, I consider, is a very serious matter, for during the past year an appeal was made to Fellows to try to obtain new members. I would again appeal most earnestly to all Fellows to use their utmost endeavours to increase our membership. If the drop continues the Society will be forced by the pressure of economy to curtail some of its activities. On this the last time I shall address you as president I do most seriously call your attention to this matter on which the whole future of our Society depends.

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There is another matter, too, which is I think of great importance to the welfare of the Society, but which for obvious reasons does not appear in the report of Council. The officers of the Society and the members of Council are elected by the votes of the Fellows at the Annual General Meeting. In practice the list that is put before you on which to vote, is prepared by the outgoing Council, a course which is followed, I think, by almost every learned society. Hitherto the list has always contained the names of three Fellows who have not served on the Council in the previous year, but there has been no standing order regulating the retirement of Fellows who had been on the Council for a long time. As a consequence it has happened in practice that many Fellows who might have been expected to make useful members of Council never had a chance of being elected, which I think has been a distinct loss to the Society. Now, however, new regulations have been made by which six members of the new Council shall not have served during the previous year, and of these, three must never before have served on the Council. Standing orders have also been made to regulate the retirement of members; I need not go into these in detail, but I may say that we have been very largely guided by the regulations in force in the Royal Society. As a result of the regulations I regret to say that we have lost the services of some very useful and valued members, but there is nothing in the regulations to prevent their names reappearing at a future date, and, such, we all hope may be the case. One loss which we all deplore is that of Mr. Mellish, who has served continuously since 1902 and who, despite the fact that he lives a long way from London and has very many other calls on his time, has been one of the most regular attendants of the meetings. I need not say how extremely sorry we are that Sir Napier Shaw is retiring from the Council. In these and in Dr. Chree and Mr. Hooker we lose the services of four ex-presidents. I must, too, especially mention Mr. J. S. Dines, who has only missed one meeting of Council in the last seven years.

During the past year the front room has been furnished and has become a comfortable reading-room where Fellows may work, or read the most recent meteorological literature. Our thanks for this are largely due to our Secretary, Commander Garbett, through whose energy it was carried out. We have also to thank him for the signed portrait of our Patron, the King, which hangs in the reading-room. I notice in the report of Council that I have presented the five frames containing photographs of clouds; but my share in the presentation is rather slender; we owe the photographs rather to the Exhibition Committee of the Royal Society, to whom they belonged as part of the Royal Society's exhibit at Wembley. Another very noteworthy gift is that from Mr. Beaufort; a mercurial barometer that was actually made by Admiral Sir Francis Beaufort, the originator of the Beaufort scale.

Another gift which the Society will receive shortly consists of a large number of MSS. books of the late Mr. Rollo Russell, for many years a Fellow and some time Vice-President of this Society. Mrs. Russell has handed the books to me and when they have been put in order I propose to hand them over to the Society. Some of you may remember that Mr. Russell wrote the account, in

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the Royal Society report, of the sunset phenomena that followed the Krakatoa eruption. There is a good deal more in the MSS. than was actually published.

I should like to mention especially the *Rainfall Atlas of the British Isles* which is shortly to be published by the help of the British Rainfall Organization Fund. The Atlas will appeal not only to Fellows of this Society, but to a very wide public. There will be in all 71 maps printed in colour, and beautifully reproduced. The Committee which has charge of this publication has had the great advantage of securing the help of Dr. Mill, who is writing the introduction.

In the past year we have reorganized our financial arrangements and have paid off a part of our debentures by the sale of investments. You will find details of the transaction in the report of Council. Our thanks are due to our Treasurer, Mr. Druce, for these financial arrangements which are of distinct advantage to the Society.

And now I am afraid I am going to break a recent tradition which expects a president to give two addresses during the course of his tenure of office. My own share in original work in meteorology is somewhat slender, and accordingly this year instead of giving you a presidential address I propose to show you a series of lantern slides of cloud photographs.

The taking of cloud photographs has exercised a fascination for meteorologists and for many others. There are many different ways of taking clouds, and I may briefly refer to my own methods. The photographs are taken on panchromatic plates with a colour filter. They are developed in a tank, and given a fairly full development. As a result the negatives are what photographers describe as rather contrasty, and often the sky comes out nearly black; this result is aimed at especially in the case of cirrus clouds. Latterly deeper screens have been gradually used and longer exposures given. A long exposure and a short development will often enable one to get the clouds without getting the landscape too dark, which is an advantage from a pictorial point of view. For the structure of fine cirrus, however, one should develop fully.

Mr. Cave then showed a large and interesting collection of slides.

Winter Thunderstorms.

In the table under the above heading in the January number of the *Journal*, under the column for the British Isles the following corrections should be made :—The total for February should read 23 and that for 1923, 52, and not 20 and 42 as given respectively.

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THE METEOROLOGICAL RESULTS OF THE MOUNT EVEREST EXPEDITION.

A. THE OBSERVATIONS.

By T. H. SOMERVELL, M.A., M.B.

[Received October 23, 1924—Read February 17, 1926.]

During the Everest Expedition of 1924, it was understood that the chief gap in meteorological knowledge which this expedition might possibly fill was the question of surface temperatures at great heights. Accordingly, when the several camps were established on the East Rongbuk Glacier (the camps being, roughly, at 2,000 ft. intervals in height one from another), each was provided with a set of thermometers for recording temperatures at fixed times—8 a.m., 12 midday and 4 p.m.—and also for registering minimum temperatures during the night. Experience had already persuaded me that maximum temperature observations were almost impossible under the conditions and would yield unreliable and valueless results. The maximum temperature readings are available for reference in the records of the Royal Geographical Society. At a few camps the temperature of the snow was taken and kata-thermometer observations were also made.

The thermometers for recording maximum and minimum temperatures were all placed on wooden ration boxes, one foot or thereabouts above the ground, in (as far as was possible) similar conditions, and in the shade, while the air temperatures at 8 a.m., midday and 4 p.m. were taken by swinging a thermometer.

Black fur was often tested, and on a clear day it was only a matter of patience to record anything that the thermometer could read to. Over 120° F. was recorded at 23,000 ft., 95° to 115° F. at 19,500 ft., and at the base, 95° to 115° F.; but, by waiting, one could usually persuade the thermometer to go up above its scale at any camp.

Dry kata-thermometer readings varied from 6 secs. on a cold windy day (averaging about 15 secs.) to 90 secs. towards the end of our climbing season and the beginning of the monsoon.

It must be remembered, however, that the performance of any little extra work, such as even the recording of a temperature, is very irksome at high altitudes, but, none the less, a fair number of records were made, and although one has to apologise for the imperfections in the taking of the observations, considering the difficulty of the conditions it is remarkable that, on some days, observations were made at all, and for these the greatest credit is due to those members of the expedition who summoned up the strength to swing a thermometer for five minutes, or to go out into a blizzard to see what was last night's minimum. Nevertheless, on certain days quite good series of observations were taken

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simultaneously at three, four or five of the camps,[1] and it is those series which it is hoped will prove of most value in determining the variation with height of surface temperatures.

Both dry and wet bulb readings were taken on the journey through Tibet, but it was found impracticable to continue them at the Base Camp. These records, together with brief notes of wind and weather, are given in Table I.

TABLE I.—Observations taken in Tibet.

Date.	Place.	Altitude (feet).	Weather.	Wind.	Min. °F.	Dry. °F.	Wet. °F.	Diff. °F.
April								
7	Phari .	14,300	Cloudy.	SSE.	12	37	31	6
8	Lungwe .	15,500	Snowy.	SW-N.	4	34	29	5
9		16,000	Fine.	Light SW.	−2	45	30	15
10		16,500	,,	Light WSW.	−1	—	—	—
11	Kampa .	14,700	,,	W.	22	63	43	20
12	,,	,,	Overcast.	Light SW.	17	65	46	19
13	,,	,,	Fine.	Light W.	11	65	50	15
14	,,	,,	Cloudy.	Light W.	9	62	51	11
15	Mende .	15,000	,,	Strong SW.	11	—	—	—
16	Tinki .	15,300	,,	SW.	11	—	—	—
17	,,	15,300	Fine.	SW.	16	50	41	9
18	Khanga .	14,700	,,	Calm.	16	—	—	—
19	Chiblung .	13,600	Cloudy.	Light SW.	13	53	39	14
20	Jikkyop .	13,300	,,	Light SW.	14	54	42	12
21	Trangso .	13,400	Fine, cloudy.	SW.	11	53	43	10
22	Kyishong .	13,900	Fine.	Calm.	29	50	39	11
23	Shekar .	14,300	Cloudy.	Calm.	14	—	—	—
24	,,		Overcast.		—	54	40	14
25	Pangla .	13,900	,,		13	45	35	10
26	Tashidzom .	15,000	Fine.	Gusty NW.	25	47	33	14
27	Chödzong .	15,300	,,	Calm.	14	48	32	16
28	Rongbuk .	16,100	,,	Strong WSW.	17	41	31	10
29	Base Camp .	16,500	Snowy.	Strong S.	10	33	32	1
30	,, ,,	,,	Fine.	Light S.	13	—	—	—
May								
1	,, ,,	,,	Cloudy.	Calm.	13	58	41	17
2	,, ,,	,,	Fine.	Strong SW.	15	51	37	14
3	,, ,,	,,	Snowy.	,, ,,	13	—	—	—
4	,, ,,	,,	Fine to overcast	,, ,,	15	38	32	6
5	,, ,,	,,	Snow showers, otherwise fine.	Gusty S.	—	50	35	15

The remaining tables contain:

1. The weather notes made at the various camps (Table II.), the material for which was supplied by the Royal Geographical Society;
2. The temperature records (Table III.); and
3. Additional observations taken at the Base Camp (Table IV.).

[1] The observations are not quite comparable owing to the different situations of the various camps which were as follows:—

Base Camp (16,500 ft.) in the bed of a valley N-S, sheltered by a moraine heap from S. winds.
No. 1 Camp (17,800 ft.) in the bed of an open valley E-W.
No. 2 ,, (19,500 ft.) in the bed of a small valley.
No. 3 ,, (21,000 ft.) in a valley NE-SW, sheltered on the SW.
No. 4 ,, (23,000 ft.) on a snow shelf facing NE, sheltered on SW from the prevailing winds.

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TABLE II.—The Weather Diaries kept at the Camps. Base Camp 16,500 ft., Camp I. 17,800 ft., Camp II. 19,500 ft., Camp III. 21,000 ft., Camp IV. 23,000 ft.

April 29. *Base Camp.* Bitter cold day, snowed all p.m. lightly and cleared at sunset. A hopeless day on the mountain.

April 30. *Base Camp.* Complete change in weather. Mountain clear bar usual cloud barrier all day. Wind not excessive. Judge it a good climbing day.

May 1. *Base Camp.* Mountain mostly clear but light snow showers in p.m.

May 2. *Base Camp.* Weather clear and very windy in a.m. Grew less windy but more cloudy later, and in the evening again partially cleared and became more windy.

May 3. *Base Camp.* Weather on mountain bad all day. Cloud and wind in a.m. and snowstorms in p.m. Cold all day.
Camp I. Afternoon and evening cloudy; night windy.

May 4. *Base Camp.* High up there was bad weather all day with a strong wind and much cloud. At the Base Camp we had a sunny morning and a cloudy afternoon with a cold wind.
Camp I. Morning clear (not calm).
Camp II. By noon the day was clouded and the sun hardly appeared later.

May 5. *Base Camp.* Snow fell for an hour or two from about 2 a.m. Much cloud and wind on mountain, but weather improving all day and completely clear by the evening.
Camp II. High wind in night. Considerable fall of snow.
Camp III. No observations; instruments still at Camp II. Bitterly cold after sun went down. Windy night.

May 6. *Base Camp.* Weather very much improved—less windy than usual. Looked like a possible day on the mountain if wind were not too high.
Camp I. Gorgeous p.m. Mountain in climbing order all day apparently.
Camp II. A very fine, clear night. Still. During the day, fine weather, gusts of wind. Wind all day from West on Everest.
Camp III. Extremely clear atmosphere. Wind blew up E. Rongbuk Glacier until corner was turned leading to North Col. Very cold night.

May 7. *Base Camp.* Beautiful weather. No wind either here or apparently on the mountain.
Camp I. Glorious day, no wind, warm sun. Direction of evening breeze SW.
Camp II. Beautifully fine day. No wind at Camp. Gentle wind on mountain, but very fine, calm weather. No clouds all day.
Camp III. Calm night. Sudden mild blizzard at 16.00 following very fine day with little wind.

May 8. *Base Camp.* Clear weather with very little wind. In the evening a thin sheet of cloud obscured the mountain and at 10 p.m. the sky was slightly overcast, but all was clear by midnight.
Camp I. Lovely morning, no wind and quite cloudless sun. Warm.
Camp II. Very fine day, hardly any wind, though it got up light but very keen about 4 p.m. Probably good day on mountain.
Camp III. Sunny, windy at intervals. Very windy on Everest, and in basin of North Col.

May 9. *Base Camp.* Clear at 8.30 a.m. Mountain obscured by 9 a.m. Snow began 10 a.m. and continued until some time during the night. An average of about 4 in. of snow fell with drifts up to 1 ft. and grass showing in places. Very little wind.
Camp II. Slight fall of snow during the night, odd flakes falling during breakfast-time. Snowed without ceasing all day, increasing in intensity towards evening. Breeze light and variable.
Camp III. Snow falling in morning, very light clouds and gusty wind.

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May 10. *Base Camp.* Clear and bright without much wind. It seemed to be blowing hard on the mountain, which was hidden by a cloud for a short time during the morning.
Camp I. Sunny but windy.
Camp II. Wind westerly, tearing snow off summit ridges all day. Bright sun all day. At least 6 in. of snow fell during the earlier part of the night, accompanied by a strong gusty wind. Snow naturally much drifted and depth therefore only approximate.
Camp III. Awful windy and snowy night. Blustery all day. Strong wind on mountain. Cold, snowy and blustery evening, snow drifting everywhere.

May 11. *Base Camp.* Cold in the morning, warmer later. Mountain obscured by what appeared to be a snowstorm.
Camp III. Wind, snow, no sun to speak of, almost impossible to live outside. (Camp evacuated.)

May 12. *Base Camp.* Fairly calm both in the Camp and, apparently, on the mountain. Snowstorm obscured the mountain for a short time during the morning.
Camp I. Glorious still, sunny day.
Camp II. Hot still morning. Cloud barrier on mountain, but wind evidently slight. (Camp evacuated 9.10.)

May 13. *Base Camp.* Weather clear and bright over the mountain but plenty of wind. Plateau clear in the morning but clouding up by 10 o'clock.

May 14. *Base Camp.* Mountain hopeless. A few flakes of snow in Camp. Cold but not very windy.

May 15. *Base Camp.* Weather warmer. Some wind. Mountain clear but windy.

May 16. *Base Camp.* No note. (Preparation for move up.)

May 17. *Base Camp.* Weather warm, sky cloudless. Mountain clear and apparently only slight wind on summit. White cumulus over plateau in the afternoon.
Camp I. The pleasantest day experienced so far.

May 18. *Base Camp.* Weather in the morning fine and sunny, the mountain clear. A heavy cloud over the plateau. At midday, clouds began to develop over the mountain, which by evening was almost altogether concealed.
Camp III. Weather northwards still cloudless, a good deal of cloud coming off Everest, and distinctly colder than I., but on the whole looks good and healthy still.

May 19. *Base Camp.* Weather in the morning fine. In afternoon cloudy and windy. Mountain obscured. Fresh snow on hills above 17,500 ft.
Camp I. Beautiful evening. Clear night.
Camp II. Weather fine and settled looking. 3 p.m. sleet started.
Camp III. Fine but cold.

May 20. *Base Camp.* Weather fine but windy. Mountain clear except for cloud banner. Apparently much wind on mountain.
Camp I. Bright, sunny morning, no wind.

May 21. *Base Camp.* Weather very bad. Mountain obscured all day. Snow fell in Base Camp this afternoon.
Camp II. Snow in the morning up to 8 a.m. Snow again at 1 p.m.
Camp III. Warm a.m. with a lot of cloud about. After snowing lightly on and off all day, settled down in earnest 1.30 p.m. and continued to snow for 26 hours.

May 22. *Base Camp.* Weather last night bad. Heavy clouds with much wind on mountain. Snow in Camp.
Camp II. Snowed up to 4 p.m., then cleared and became very cold.
Camp III. Snowed hard all day until 3 p.m. Cleared before sunset.

May 23. *Base Camp.* Morning clear and with little wind. Mountain clouded over in afternoon. Slight snowfall in Camp.
Camp I. Glorious weather here, but high wind above.
Camp II. Bright sunny morning. Snow clouds came over about 3 p.m. Snowed later. Lightning to S. at night.

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Camp III. After coldest night ever recorded in these parts, morning broke brilliantly fine. Gorgeous hot morning. Snow falling lightly 2.15 to 3 p.m. Snowing hard about 5 p.m. Weather looks exactly like monsoon. Heavy, soft snow up to midnight.

May 24. *Base Camp.* Day windy and cloudy. Mountain partly obscured.
Camp II. Bright all day. Snow fell at night, blowing up from E.

May 25. *Base Camp.* Weather distinctly changed. Moderate wind up the valley from Tibetan Plateau. Warmer. Much cloud over plateau and moving southward. Mountain clear in morning, but later in the day obscured in cloud.
Camp I. Sunny, but not very warm.
Camp II. Cloudy but still.
Camp III. Weather fine and very cold, but clouds coming over Rapiu La. from S.E. (Camp evacuated.)

May 26. *Base Camp.* Weather fine in morning. Cloudy and windy in afternoon with mountain obscured.

May 27. *Base Camp.* Weather fair. Wind moderate. Warmer. White cumuli over mountain but no indication of snowfall.
Camp I. Fine day. Wind high WSW.

May 28. *Base Camp.* Weather good. Warm. Slight clouds. Mountain for the most part clear.
Camp I. Fine day, as yesterday. Calm here but strong wind high up (27,000 ft. or so) WSW.

May 29. *Base Camp.* Weather very fine and warm. Moderate wind. Mountain clear with only occasionally a trace of cloud.
Camp I. Slightly windy but very fine, looks settled. (Later) sunny, warm, slight wind, Everest cloudy. Clouds in W. Rongbuk Basin.

May 30. *Base Camp.* Weather very fine and warm. Mountain cloudless and remarkably clear.
Camp I. Cloudless morning, warm, wind slight, blowing up valley, normal.

May 31. *Base Camp.* Weather fine. Mountain clear all day.
Camp IV. Weather sunny and calm (warm). Rather heavy snow conditions on Col slopes. Everest very clear all day.

June 1. *Base Camp.* Weather perfectly clear and fine. Mountain without a cloud all day.
Camp IV. Calm.

June 2. *Base Camp.* Glorious day, though considerable wind. Mountain cloudless all day.
Camp III. Cold, windless night. Cloudless, cold, windless morning.
Camp IV. Calm, fine morning.

June 3. *Base Camp.* Cloudless sky. Occasional wisps on mountain. Strong wind.
Camp IV. Bright, clear and calm, wind very cold and strong on N. ridge. Cold "Arctic" sky to eastward at sunset, pink and intense livid hues.

June 4. *Base Camp.* Another perfect day; only a strong breeze.
Camp IV. Brilliant weather. 4.15, calm and clear.

June 5. *Base Camp.* Cloudless, windless day. Simply perfect. Doubtful-looking clouds behind, *i.e.*, to south of Everest, at sunset.
Camp IV. Calm and clear.

June 6. *Base Camp.* Fine, still morning. Everest clear, but mist and heavy cloud came up in afternoon, completely hiding Everest by 4 p.m. First sign of monsoon.
Camp III. About midday the weather began to change and clouds rose up from every direction. A few flakes of snow fell in III. at 6 p.m. and a fair amount on the mountain. Night warm.
Camp IV. Calm and cold. Midday brilliant. Clouds in valley and to east 4.45. Air still, thick mists all round, obscuring summits, including Everest, light mists hanging round Camp V. (25,000 ft.).

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June 7. *Base Camp.* Fine, still morning. Clouds began to advance up valley. Rain at 1 o'clock. Clouds behind and on Everest from 11 o'clock onwards.
Camp III. Clear morning, but clouds rolled up in p.m.
Camp IV. Calm, cloudy. 12.00. Calm, very close, clouds and mist on mountain. Camp IV. in sunshine. 16.00. Calm, very close, clouds and mist.

June 8. *Base Camp.* Fine morning, but clouds constantly round Everest.
Camp III. Misty morning. Mountain only occasionally in view.
Camp IV. Cloudy, occasional gusts of wind. Mist, mountain almost entirely obscured, calm and very close. 12.00, calm and very close. 16.00, calm, clouds inclined to lift, patches of dew, etc.

June 9. *Base Camp.* Dull sky; very monsoony. Everest clear.
Camp IV. Clouds and mist, occasional gusts from W. 12.15, clouds and wisps of mist blowing from W.; close and fairly calm. Mountain occasionally clear. 16.30, clear, clouds to E. Snow on mountain. Wind from W. appears to be of high velocity. Mountain clear. Camp sheltered but wind can be heard above occasionally. Cloudy E.

June 10. *Base Camp.* Weather clear over Everest, but light monsoony clouds very high most of afternoon and evening.
Camp IV. Calm, mist in the early morning. Calm, light clouds, mountain clear. Clouds to E. decidedly monsoonish looking. Mountains appear very near. 12.30, mountain clear on N. side. Camp sheltered. Strong wind blowing above from W. 16.00, light clouds, wind, high wind above. Mountain smoking along ridge.

June 11. *Base Camp.* Brilliant, fine day like pre-monsoon.
Camp II. (Camp finally evacuated.)
Camp IV. Sunny, calm, high cirrus. (Camp evacuated at 10.15 hrs.)

B. SOME LESSONS FROM THE OBSERVATIONS.

By F. J. W. WHIPPLE, M.A.

These meteorological observations made by Dr. Somervell and his colleagues are valuable as a record of the conditions under which the climbers worked, and are also interesting as evidence of the physical processes in the atmosphere.

Table I. illustrates the climate of Tibet. The dryness of the air is shown by the large difference between the dry and wet bulb thermometer readings, but it is to be noted that with the same relative humidity evaporation reduces the temperature of the wet bulb further at great heights than at sea level. Thus the readings at Kampa—dry bulb 63°, wet bulb 43°—would imply[2] a relative humidity of 10 per cent. at sea level, but at 14,700 ft. the relative humidity is computed as about 30 per cent. Attention may be called to the persistent low readings of the minimum thermometer, below 20° F. on all except three nights. These readings, like those made at the various camps on Mt. Everest, refer to thermometers with their bulbs fully exposed and about one foot above the ground or snow. The readings are comparable with the "grass minimum" temperatures of our climatological stations rather than with the air temperatures given by thermometers in the shade of a louvred screen.

[2] This is on the assumption that the dry and wet bulb thermometers were swung. The dry bulb temperatures shown in Table I. for the Base Camp are persistently higher than the readings of the sling thermometer in Table II. For May 1 the difference is 10° F. This makes the assumption doubtful.

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FIG. 1.—The Base Camp at 16,000 feet.

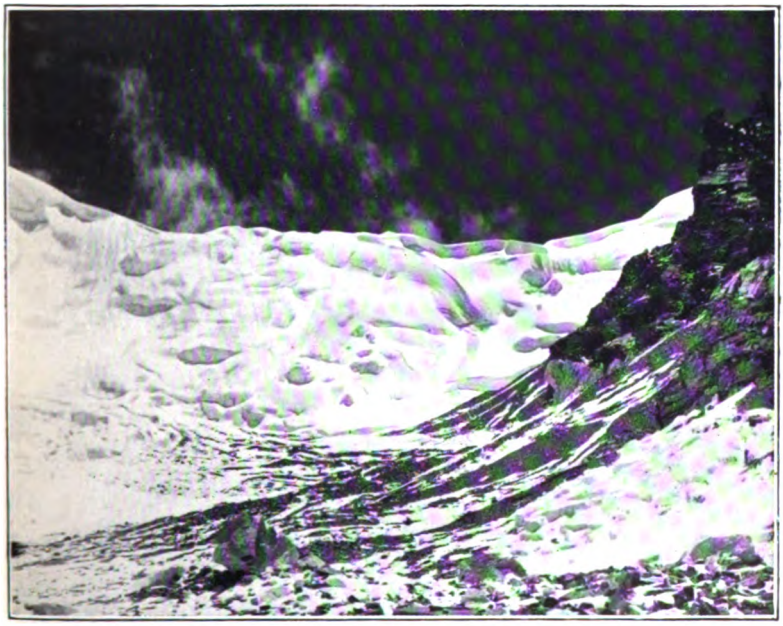

FIG. 2.—The approach to the North Col from Camp II.

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FIG. 3.—Camp IV. as it appeared in 1922.

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With the Weather Diary of Table II. we can follow the history of the attacks on the mountain. The expedition reached the Base Camp[3] at the end of April and left in the middle of June. All through May there was a wave of cold and wet weather over Northern India, brought by strong winds from the west. According to the *Indian Monthly Weather Report*, as many as six disturbances of the cold weather type passed into North-west India from the west during the month. It was the second of these which was responsible for the forty-eight hours of continuous blizzard experienced by the Everest party on the 10th and 11th. The advanced camps were vacated. It was at this time that one porter fell into a crevasse and broke his leg, one died of frostbite and a third of cerebral hæmorrhage. The retreat of the expedition is responsible for the gap in the meteorological observations at the higher stations. For the final effort the weather was extremely favourable. It was on June 8 that Mallory and Irvine were last seen, 600 ft. from the summit. The circumstances give a strong human interest to the last entries in the Weather Diary.

Turning to Table III., we notice in the first place that the readings printed in italic type were made on a thermometer which was not intended for the work and was probably inconvenient for swinging. The readings seem to be inconsistent with the rest, and it has been thought best to ignore them in the following discussion.

The lapse of temperature with respect to height.

Owing to the care with which it was arranged that observations of temperature at the various camps should be simultaneous, there is excellent material for studying the relation of temperature to height under different conditions. The standard of comparison for this purpose is the "dry adiabatic" lapse-rate. When the atmosphere is well stirred up by being heated at the bottom or by violent winds, the distribution of temperature should theoretically be such that for every 1,000 ft. rise in height the air is colder by about $5\frac{1}{2}$° F. On the slope of a mountain the temperature is not quite the same as in the free air at the same level, but when the slope is steep the difference may be expected to be very small. Accordingly we should expect to find this theoretical lapse-rate nearly approached in favourable circumstances, but seldom, if ever, surpassed. On the other hand, as stratification in which cold air is below warm air is stable, there is no mechanical difficulty in supposing the air lower down the valley to be cooler than that on the upper slopes.

The lapse under adiabatic conditions for 16,500 ft. to 19,500 ft. would be about 17° F. According to the observations, the lapse between the Base Camp and Camp II. reached 17° on one occasion and 18° three times.

Similarly, the anticipated maximum difference between the Base Camp and Camp III. was 25°. The observations give 24° three

[3] Our illustrations show (1) The Base Camp at 16,500ft., (2) The approach to the North Col (Camp IV.) from Camp II. and (3) Camp IV. as it appeared in 1922. The site of Camp II. was close to the "Sirac" on the East Rongbuk Glacier illustrated in the *Quarterly Journal*, Vol. 49, 1923, p. 275.

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times, 25° three times, and 26° twice. One observation, that at 16 h. on May 31 at Camp III., is probably in error and must be rejected. The reading, 22° F., is hardly consistent with the note in the Weather Diary at Camp IV.—"Weather sunny and calm (warm)"—and the difference from the 41° at Camp II., only 1,500 ft. lower, is too great. The theoretical maximum lapse from the Base Camp to Camp IV. is about 36° F. Actually 34° F. was recorded on two occasions.

On the other hand, small lapses of temperature were fairly common. Only on one occasion was temperature the same at the Base Camp and at Camp II. at 19,500 ft., on the morning of May 19, but there were eight mornings (out of the nineteen for which we have observations) with a lapse not greater than 5° F. The lapse was reported as 4° F. on May 18 at 16 h., but as conditions were favourable for convection at the time and the reading 40° is suspiciously high, a 10° error is likely. The lowest authentic lapse between the Base Camp and Camp II. at 16 h. is 8° F. in the blizzard of May 21. The lowest at noon is 6° F. on May 9, also in a snowstorm. 6° F. is the difference of temperature between the Base Camp and Camp III. on the afternoon of May 9. On this occasion, in a blizzard, the reported readings are 18° F. at the Base, 9° F. (below the graduations on the thermometer) at Camp II., and 12° F. at Camp III.; otherwise the smallest lapse between the Base and Camp III. was 12° F. on May 10. In this case there was wind at the greater height and calm below.

The minimum lapse from the Base to Camp IV. was 13°; it occurred on a fine but misty morning, June 10. There are only two other morning observations available for comparison.

The average lapses from the Base to the other Camps are shown below:

	Camp II.	Camp III.	Camp IV.
Height in ft.	19,500	21,000	23,000
Height in ft. above Base	3,000	4,500	6,500
Dry Adiabatic Lapse of Temp., °F.	17°	25°	36°
Maximum Lapse observed, °F.	18°	26°	34°
Minimum " " °F.	0°	6°	13°
Average Lapse, 8h. 30m., °F.	7° (19)	20° (9)	17° (3)
" " 12h., °F.	13° (16)	18° (4)	26° (7)
" " 16h., °F.	12° (17)	21° (6)	29° (8)

The number of observations used to determine the several lapses is shown in brackets. It has of course to be borne in mind that the observations at Camps III. and IV. do not refer to the same dates or to the same type of weather.

The lowest air-temperatures recorded by the expedition were observed at Camp III. on May 10. The weather diary for the camp shows that there was strong wind all day and a cold, snowy and blustery evening. Between noon and 16 h. 30 m., temperature fell from 22° to 5°, and by 18 h. it had gone down to −2° F. The reading next morning at 9 h. was 1° F. This last reading was practically simultaneous with 27° F. at the Base Camp, so

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that it appears that under these rough conditions the air is as well stirred as it is by the convection currents of sunny weather.

Diurnal Variation of Temperature.

At the Base Camp the diurnal variation of temperature was well marked. In fine weather the rise of temperature between 8 h. and noon was seldom less than 10° F. The greatest rise, 20° F., occurred on June 3, a bright, clear day, with the wind very cold and strong on the mountain. On this occasion the temperature was 35° F. at 8 h. and 55° F. at noon. There was probably an inversion of temperature. No observations at higher camps are available on the morning in question, but on the next two mornings there was only a difference of one or two degrees between the readings at the Base Camp and at Camp II., 2,500 ft. higher. The only explicit evidence for an inversion in the morning was on May 7, when the temperature at the Base Camp was 27° F. at 8 h. and the reading at Camp I., 1,300 ft. higher, was 28° F. The note in the Base Camp diary is "Beautiful weather. No wind either here or apparently on the mountain." As a general rule in fine weather the fall of temperature between noon and 16 h. was about 3° F. Occasionally the fall was greater, as for example on May 6 and 7; for the former day we have the note "Gorgeous p.m."; for the latter, "Glorious day, no wind, warm sun, evening breeze SW"; on both days temperature was 42° at noon and 36° at 16 h. Occasionally, in changing weather conditions, there was a large difference between the noon and 16 h. temperatures. On May 4 it clouded at 12 and there was no sun later; temperature fell from 44° to 27° in the four hours. On May 21 and again on the 23rd, snow fell in the afternoon; temperature dropped from 48° to 33° on the one day, from 41° to 33° on the other.

The number of reliable observations at Camp I. is too small to allow of generalizations.

At Camp II., 19,500 ft., the rise in temperature between 8 h. and noon was usually very small, about 2°F. Occasionally it was greater. On June 7 the morning reading was 35° and at noon the reading was 47°. On this morning and on the preceding and following mornings the cold night air must have been resting on the mountain slope at 8 h. In fine weather there was a small drop of temperature at this station between noon and 16 h., the average being about 3° F.

The longest spell of observation at Camp III. at 21,000 ft. was in bad weather and the observations throw no light on the regular diurnal changes of temperature. The observations at Camp IV. indicate for fine weather practically no change in temperature throughout the day.

With regard to the readings of the minimum thermometers, set out in Table III., it is of course to be understood that these do not represent measurements of air temperature at all. The minimum thermometers were exposed in such a way that their temperature would be determined as much by radiation as by contact with the air. Unfortunately we do not know the temperature of the air in the middle of the night, but in view of the fact that at the upper camps there was little regular diurnal variation of temperature, we

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TABLE III.—Thermometer Readings.

	Air Temperature by Sling Thermometer.															Minimum Temperature thermometers exposed to sky about 1ft. above gro			
	Base.			Camp I.			Camp II.			Camp III.			Camp IV.			Base Camp.	Camp I.	Camp II.	Camp III.
Height	16,500ft.			17,800ft.			19,500ft.			21,000ft.			23,000ft.						
Hour.	8½	12	16	8½	12	16	8½	12	16	8½	12	16	8½	12	16				
1924.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	F.	°F.
May 1	33	42	48	—	—	—	—	—	—	—	—	—	—	—	—	13	—	—	—
,, 2	33	44	47	—	—	—	—	—	—	—	—	—	—	—	—	14	—	—	—
,, 3	33	43	—	—	—	—	—	—	—	—	—	—	—	—	—	13	*10**	—	—
,, 4	31	44	27	—	—	—	(At 10h., 10°).			—	—	—	—	—	—	11	—	—	—
,, 5	27	43	35	—	—	—	(At 9½h., 17°).			—	—	—	—	—	—	−4	—	1	—
,, 6	29	42	36	—	—	37	(At 10h., 20°).			—	—	12	—	—	—	−11	—	−8	—
,, 7	27	42	36	28	—	—	—	—	27	—	18	11	—	—	—	6	5	−5	−21
,, 8	26	39	30	—	—	—	—	—	29	17†	24	13	—	—	—	15	7	−1	−13
,, 9	33	24	18	—	—	—	19	18	9	14‡	—	12	—	—	—	12	—	3	−9
,, 10	26	34	27	—	—	—	19	25	15	12	22	5‖	—	—	—	13	—	−9	16
,, 11	27	32	—	—	—	—	19	—	22	1‡	—	—	—	—	—	7	—	2	−7
,, 12	25	36	35	23	38	—	22	—	—	—	—	—	—	—	—	7	12	0	—
,, 13	31	38	—	—	—	—	—	—	—	—	—	—	—	—	—	7	—	—	—
,, 14	36	35	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—
,, 15	33	35	—	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	—
,, 16	27	44	41	—	—	—	—	—	—	—	—	—	—	—	—	13	—	—	—
,, 17	39	46	46	—	—	45	—	—	—	—	—	—	—	—	—	10	—	—	—
,, 18	40	45	44	36	—	—	—	—	40*a*	—	—	—	—	—	—	11	10	—	—
,, 19	37	46	44	*33*	—	—	37	36	26	—	—	—	—	—	—	11	*14*	0	—
,, 20	34	46	43	—	—	—	—	34	30	—	—	—	—	—	—	12	−2	—	−8
,, 21	37	48	33	—	—	—	31	33	25	17	—	—	—	—	—	23	—	—	4
,, 22	34	32	36	—	—	—	—	23	15§	—	—	11	—	—	—	8	—	—	5
,, 23	36	41	33	—	—	—	21	—	24	17	—	—	—	—	—	10	—	0	−24
,, 24	31	38	36	—	—	—	—	—	—	7	—	—	—	—	—	12	—	−2	−16
,, 25	32	39	42	—	—	*53**	27	—	27	14	—	—	—	—	—	13	*14*	0	−13
,, 26	42	49	42	—	*48*	—	31	33	33	—	—	—	—	—	—	14	*14*	0	—
,, 27	36	49	42	*25*	*52*	—	33	—	30	—	—	—	—	—	—	15	*10*	0	—
,, 28	35	50	43	*34*	*48*	*46*	34	39	35	—	—	—	—	—	—	16	*18*	−13	—
,, 29	42	52	50	*36*	—	—	—	41	37	—	—	—	—	—	—	14	—	10	—
,, 30	39	52	51	—	—	—	—	—	—	—	—	—	—	—	—	12	—	13	−20
,, 31	42	57	55	—	—	—	37	43	41	17	—	22*a*	—	—	—	10	—	13	0
June 1	41	54	53	—	—	—	34	40	—	—	—	—	—	—	19	13	—	12	—
,, 2	39	56	53	—	—	—	—	39	—	20	—	—	—	—	—	13	—	13	−4
,, 3	35	55	50	—	—	—	—	—	41	—	—	—	—	—	—	12	—	13	—
,, 4	38	56	55	—	—	—	37	38	—	—	—	—	—	29	23	11	—	13	4
,, 5	40	58	55	—	—	—	39	42	—	—	—	—	—	32	32	12	—	18	4
,, 6	45	60	57	—	—	—	37	—	39	—	40	—	—	36	23	21	—	20	5
,, 7	48	60	59	—	—	—	35	47	45	—	—	—	—	35	30	22	—	22	2
,, 8	51	58	55	—	—	55	38	—	—	—	—	—	28	36	29	25	—	—	—
,, 9	—	59	53	—	—	—	—	—	—	—	—	—	29	27	27	26	—	20	—
,, 10	42	54	49	—	—	—	38	39	—	—	—	—	29	29	30	21	—	17	—
,, 11	41	57	53	—	—	—	—	—	—	—	—	—	25	—	—	23	—	13	—
,, 12	37	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	—	—	—
,, 13	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—

* Figures in italic type converted from Centigrade. † At 9¾h. ‡ At 9h. ‖ Also −2 °F. at 18
§ At 18h. *a* Doubtful readings, see p. 138.

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may be certain that the readings at 8.30 were not as a general rule much above the true minima.

The difference between the recorded minimum and the lower of the readings at 16 h. on the preceding evening and 8 h. 30 m. the following morning was as much as 43° F. at Camp II. on May 28, 33° F. at Camp III. on May 7, and 35° F. at the same camp on May 23. These figures show how effective radiation is with clear skies and a thin atmosphere. Probably the low readings give a better idea of the conditions to which the mountaineers were exposed than could have been obtained from true air temperatures. It is well known that the long-wave radiation from air is largely due to the water vapour it contains. At these great heights there is but little water vapour and therefore the radiation which comes from the sky at night is much less than at lower levels. This is one of the reasons for the low readings of these exposed thermometers.

Comparison with Temperatures in India.

The temperatures recorded on Mount Everest may be compared with those prevailing at the same time at the Indian hill stations and in the free air over the Indian plains.

From the *Indian Monthly Weather Report* for May and June, 1924, we find that at Darjeeling, 7,000 ft. above sea level and about 100 miles away, the mean maximum temperature for May was 65.3° F.; that for June, 60.6° F. It will be seen that in May the Base Camp on Mount Everest at 16,500 ft., with an average temperature at midday of 42° F., was the cooler by 23° F., the difference being about 2½° F. per thousand feet. In June, however, the temperature at the Base Camp at noon averaged (during the first eleven days of the month) 57° F., so that it was only 4° F. lower than the average (for the whole month, it is true) at Darjeeling.

The average temperatures at specified heights over the Indian plains have been determined by Harwood from the balloon-soundings at Agra. His figures are equivalent to the following:—At 5 km. (16,500 ft.) the averages for May and June are 25° F. and 35° F. respectively. At 7 km. (23,000 ft.) the averages are 0° F. and 17° F. for these two months.[4]

Even in the morning at 8 h. 30 m. the readings on Mount Everest were about 10° F. above the free air temperatures for the same heights. On exceptionally clear cold nights the temperature on the mountain slopes was about the same as that of the free air.

Black fur and kata-thermometer temperatures.

With regard to the observations with the kata-thermometer and with fur, Dr. Leonard Hill has been so good as to supply the following notes:

"The 'kata' factor may be taken as 480 (this is not stated but it is about the usual figure). The lowest cooling power in millicalories per sq. cm. per sec. is then, on June 6, 480 ÷ 86, or

[4] Harwood, W. A., "The Free Atmosphere in India," *Calcutta, Ind. Met. Mem.*, **24**, 1924, p. 178. The averages are based on six night observations in May and ten in June.

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approximately 6, which is the cooling power obtained only on very close days in England when the kata-thermometer is fully exposed, but which is common in a confined city court. It is the standard cooling power for rooms. The highest cooling power is 480 ÷ 9 (May 3) = 53, which is the cooling power obtained in England with a very cold winter wind. Dr. Somervell says a cooling in 6 secs. was obtained. This gives a cooling power of 80, which is higher than anything I have measured in England, but probably not higher than on a very cold windy night in England. The cooling rates obtained indicate as a whole cooling powers obtained in England in cold windy weather in fully-exposed places.

"The black fur temperatures are very high, indicating the great heating power of the sun on dark clothes and the high radiant energy of the sun. On a July sunny day in England I have obtained black fur readings of 60° C. when the air temperature was, say, 20°C. Dr. Somervell does not say what the scale of his thermometer went up to, but evidently the black fur could raise the thermometer well above the scale. The recorded figures are not above those obtainable on a July summer day in England at noon. A vacuum black bulb temperature of 105° C. has, I believe, been recorded in the Himalayas."

TABLE IV.—ADDITIONAL OBSERVATIONS AT THE BASE CAMP (16,500ft.).

Date. 1924.	Barometer at 8.30 a.m. Ins.	Black Fur. Temp. °F.	Black Fur. Hour.	Kata-Thermometer (noon) secs.	Date. 1924.	Barometer at 8.30 a.m. Ins.	Black Fur. Temp. °F.	Black Fur. Hour.	Kata-Thermometer secs.
May					May				
1	16.18	97		14	24	16.20	69	16	17
2	15.92	84		10	25	16.25	85	16	24
3	15.98	—		9	26	16.26	No sun		25
4	16.03			18	27	16.25	102	16	26
5	16.10			14	28	16.10	No sun		20
6	16.05	71	16	17	29	16.30	102	16	31
7	16.225	74	16	19	30	16.30	S'n obsc'd		28
8	16.125	68	16	22	31	16.30	120	16	30
9	16.05	No sun		14	June				
10	16.05	70	16	16	1	16.25	106		27
11	16.28	—		23	2	16.30	106		26
12	16.28	75		24	3	16.375	98		32
13	16.62	—		19	4	16.275	102		29
14	16.375	—		34	5	16.225	99		65
15	16.14	—		24	6	16.50	No sun		86
16	16.125	115	8.30	22	7	16.15	88		53
17	16.10	104	16	44	8	16.25	—		
18	16.10	87	16	40	9	15.98	124	12	
19	16.05	87	16	40	10	16.43	—		
20	16.15	86	16	22	11	16.36	123	16	28
21	16.22	No sun		24	12	16.38			
22	16.05	No sun		17	13	16.35			
23	16.15	No sun		12					

DISCUSSION.

Mr. L. C. W. BONACINA said he would like to refer to the point about the scarcity of the inversions of temperature mentioned by Mr. Whipple. In that part of the world there was known to be a rather

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high lapse rate which would often manifest itself in bad weather due to instability, and probably a great deal of the unexpected snowfalls before the burst of the monsoon that the party encountered had their origin in local instability. If the expedition went again, he thought it was a matter which should be borne in mind. There was another thing he thought the expedition might ascertain: what was the level of the maximum snowfall on the summit of the Himalayas? Did it occur above or below 20,000ft.? It would seem that the temperature at the very highest levels would be too cold for an excessive amount of snow. He recollected reading that the natives declared that the maximum snowfall kept well below the highest levels, and perhaps if the climbing party had waited, they would have had better weather. There did seem to be a certain amount of theory to support the natives' point of view.

Dr. G. C. SIMPSON said he thought the Society ought to be very grateful to Mr. Whipple for having worked out these results and for presenting the whole paper. He did not wish in the least to detract from the work which Mr. Whipple had done, but he must point out that there was still very much work to be done with these observations. He thought he would leave comments on the meteorological conditions of India to the President, who would be able to tell the meeting very much about them: but he would like to point out that one of the chief problems of the meteorology and climatology of India was connected with the winter depressions. He thought that the expedition had been unlucky enough to encounter three or four, or even more, of these depressions, but of course from the meteorological point of view they were not unlucky to have met with such conditions, as they had had an opportunity of studying them. Nothing was known of the mechanism of the depressions; they wanted to know whether they had warm or cold fronts, and to find out what the meteorology of the upper atmosphere was. He was certain that these observations would, some day, be of use for that purpose. It would probably be a very long time before such observations would be again obtained, and those discussed to-night were extremely valuable from that point of view. The very difficulties which the expedition met with owing to bad weather made the results remarkable and useful, and there was still a considerable amount of information to be got out of them. So far we had only got the results of less value and interest, but Mr. Whipple had put the observations in a form which he was sure would be very convenient for future work.

The PRESIDENT (Sir Gilbert T. Walker, F.R.S.) said that he only wished it had been possible to arrange and discuss the results of the previous Himalayan expeditions as Mr. Whipple had arranged and discussed those of the Mount Everest Expedition. It might have been most helpful to the local meteorology. He wished to return the warmest thanks both to Dr. Somervell and to Mr. Whipple for the paper.

A Note on the Variability of Air Temperature over the North Atlantic in January.

The variations of temperature considered in this note are the non-periodic day to day variations. The observations used were taken from daily charts issued by the Deutsche Seewarte. The North Atlantic was divided into "squares" 5° latitude by 5° longitude south of latitude 50° N., and 5° latitude by 10° longitude north of this. For each square all the observations of temperature made by ships for ten years 1896-1905

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in January were extracted, except that if, on one day, there were two or more ships in any square, only that observation nearest the centre was taken. The numbers of observations varied greatly for different squares, but in producing the map only those squares were plotted which had one hundred observations or more, except in a few low latitude squares where the temperature was so constant that no great error could be introduced by using a smaller number.

The measure of variability used is the difference in degrees Centigrade between the upper and lower quartiles. (The upper and lower quartiles are those values above and below which, respectively, a quarter of the observations fall.) This quantity is 4/3 times the standard deviation if the distribution of frequencies is normal, and in the present case the standard deviation could be calculated from the figures given with little error.

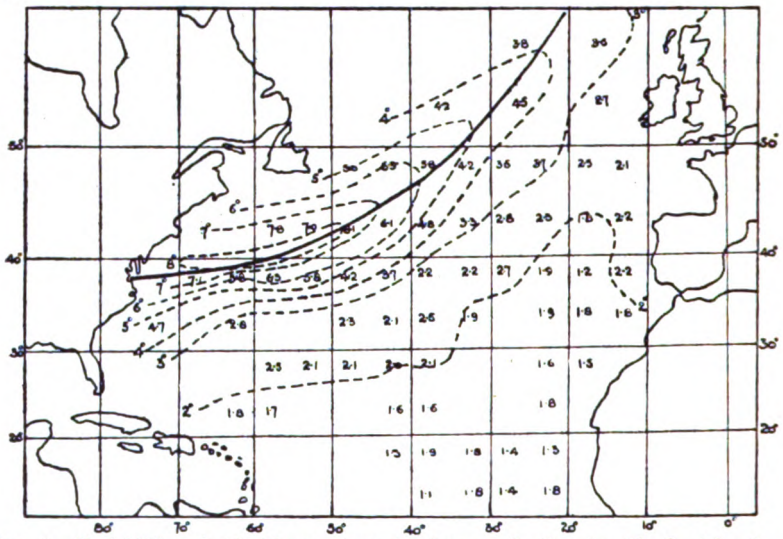

FIG. 1.—Variability of Air Temperature in degrees Centigrade, North Atlantic, January.

On the map these figures have been written in the centre of the square from which observations have been taken and isopleths drawn amongst them in the usual way. The same figures for the 07.00 h. G.M.T. temperatures at Valencia and Aberdeen have been added for comparison and the broad line with arrows shows the mean path of depressions in January as given on the charts of the North Atlantic published monthly by the Meteorological Office.

It will be noticed that the mean path of depressions lies along the ridge of the isopleths. This must be so whether we consider the discontinuity of temperature found in active depressions as the cause of the depression or as a result. It would be interesting to know if the speed or intensity varies as the ridge becomes lower to the north-east. Estimates of "continentality" based on variability of temperature ought apparently to make some allowance for the distance from the mean path of depressions.

It is remarkable that in latitude 42½° N and longitude 47½° W, so far removed from land radiation effects, the variability of temperature is almost twice that at Aberdeen. R. A. W.

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OBSERVATIONS OF WIND, WAVE AND SWELL ON THE NORTH ATLANTIC OCEAN.

By VAUGHAN CORNISH, D.Sc., F.R.G.S.

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§1. *On a Harmonious Procession of Wind and Wave.*

During the great storm of Dec. 21, 1911, the P. and O. ss. *Egypt*, in which I was returning to England, was compelled to heave-to in the Bay of Biscay. During the preceding day there had been a heavy swell entering the Bay and the violent wind which arose in the night blew in the same direction. In the early morning, the sky having cleared although the force of the wind was not much abated, the sun revealed the unusual spectacle of a single series of great waves sweeping on majestically in long lines unbroken by any cross sea. These waves rose above the 27-foot level of sight from the promenade deck, but were well below the 54-foot level of an observer stationed on the bridge. From this vantage point I could see that the whole ship's length lay between succeeding crests, and the observation was confirmed by the Commander, although from the promenade deck the wave-length appeared to me, and also to an engineer officer of the ship, to be considerably less than the length of the ship. Evidently when the observer is nearly on a level with the waves, a point on the shoulder of the advancing and of the receding wave is judged to be the summit, and the length in consequence greatly underestimated. From the bridge I recorded the intervals between the arrival of the waves at the bow, and also the time taken to traverse the length of the vessel. The ratio of period to speed[1] was in fair agreement with the theoretical formula $V = t \times 3.493$.

The question of the velocity of the wind as expressed on Beaufort's scale always becomes interesting to seamen when the force is great, and the estimates are then, I think, more reliable than during fine weather when the wind is no longer, as in the days of sailing ships, of importance to navigation. It was with much interest that I found the velocity of the waves which I had determined under exceptionally favourable conditions was not much less than the speed of the wind as logged. The velocity of the waves at 8 a.m. was 47.15 statute miles per hour (calculated from the period), the velocity of the wind, using the conversion figures of Form 317 Meteorological Office,[2] 52.5 statute miles per hour.

Many years before, on Dec. 29, 1898, I had recorded on the Dorset coast an uninterrupted series of 139 breakers with an average period of 19 seconds and therefore a calculated velocity in deep water of 66.4 miles per hour. Their arrival occupied three-

[1] Observed speed 12.15 p.m., 42.74 m.p.h. Calculated speed 12.15 p.m., 39.37 m.p.h.

[2] This Form gives a somewhat higher velocity than that formerly calculated and used in the author's paper in *J. Roy. Soc. Arts*, Nov. 1st, 1912, in which the details of the above observations are given.

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quarters of an hour. This is the greatest period I have observed in any long series of swells. The series was apparently the result of the exceptional gales in the North Atlantic from Dec. 25 to 29 in which the wind was logged at 11-12 of Beaufort's scale, which according to the later conversion table of the Meteorological Office correspond to velocities of 68 and above 75 miles an hour respectively. The greatest wind velocity recorded by instruments as maintained for one hour at a coast station during the stormy period was 70-76 miles per hour on Jan. 12, 1899.

From these experiences I thought it probable that when the wind continues to nurse the waves it finally carries them along at such a speed that conflict between wind and water has almost ceased.

§2. *The Author's Method of Measuring the Period of Waves at Sea.*

The practical difficulty which at first impeded my investigation of this idea was that of determining either the period or the speed of waves at sea from a vessel under way. The observation of the former by timing their arrival at the bow I found impossible when the waves were small on account of the disturbance made by the ship.

The direct determination of velocity by timing the passage along the ship's side is also only possible with waves of considerable size. Moreover, I have never been able to get any sure result from the promenade deck of a liner except by enlisting the co-operation of a second observer. Co-operation is useless unless continued until concordant results are obtained and such prolonged co-operation is not easy to obtain. However, during my next voyage, which was from Southampton to Colon and back in 1912, I found a quick and simple method for determining the period of the waves which enabled me rapidly to accumulate a great number of measurements, a matter of prime importance in phenomena so variable. The method consists in observing the rise of a spot of spent foam to the crest of a wave, starting the stop-watch and, having waited for the foam spot to descend to the hollow and rise on the next wave, stopping the watch when the foam again reaches the crest. The observation is then repeated and the average of ten such periods taken. They are not those of consecutive waves, but the whole set of measurements is obtained in the course of a few minutes. A second set of ten is then determined, and it has always been found that the two means are closely concordant, as examples to be cited presently will illustrate. A great advantage of the method is that it is applicable both to small and large waves, and that it enables the period of both the waves and swell to be determined, even when, as is common when the Trade Winds are blowing moderately, the sea has an extremely confused appearance owing to the over-running of the waves by a concurrent swell of the same order of length. The observations on Feb. 19, 1914, during a subsequent voyage, noon position lat. 15° 22′ N., long. 57° 1′ W., illustrate this. The weather was typical of the Trades, a strong breeze blowing, the sea of glorious blue with many white caps, and two sets of undulations running precisely in the same direction, of which the longer were much the higher and more conspicuous.

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Two series of ten intervals of the larger undulations were timed, one directly after the other. The average of the first was 7.97 seconds, of the second 8.03 seconds. The minor inequalities were similarly timed and gave periods of 6.09 and 6.24 seconds. On the morning of Feb. 28, when small waves of short and irregular front were crossed nearly at right angles by a long, high and regular swell, two succeeding sets of waves gave the periods 3.44 and 3.58 seconds. In the afternoon, when the wind had changed direction and velocity, and the swell followed at an oblique angle, the waves showed more regular fronts and two sets of ten gave periods of 2.99 and 3.09 seconds.

The fact that foam is carried along by the tide is an advantage, for it enables the true interval between waves to be determined without measuring the tidal current, but if the wind have a purchase on the foam so as to make it drift faster than the water some error would be introduced. When I first used the method of determining the period of waves from the foam spots I had already studied the action of wind upon a frothy surface, and had photographed its rippling effect. I noticed particularly that the white patches which remain for a long time on the sea are mere films, and that the wind does not deform them. It was evident, therefore, that if there were any drifting by the wind it must be slow. At length, in 1922, I was so fortunate as to obtain good conditions for measuring the amount. The place of observation was the ferry pier at Burton-upon-Stather, Lincs., near the outfall of the Trent into the Humber. A fresh breeze, the speed of which I estimated at more than 20 miles per hour, was blowing straight down the river making short steep waves, and there was much foam. At the beginning of the observations the tide was ebbing, so that the wind, wave and tide were all concurrent.

Having procured a piece of wood sufficiently dense to sink below the surface of the water so that it was not exposed to the wind, I compared the rate of drifting of the sunk wood and the floating foam, and found that the former travelled at 0.5 ft. per sec., the latter at 1.0 ft. per sec., so that the drift of the foam through the water was 0.5 ft. per sec. It could be easily seen that this drift was in a considerable measure due to the intermittent driving action of the wave crests. Presently the tide turned, the stream now flowing directly against the wind and wave, the force of the wind remaining as before. A piece of wood thrown into the river travelled up stream at the rate of 0.6 ft. per sec., the foam made its way against the waves and against the wind at 0.2 ft. per sec., so that wind and wave together retarded its motion to the amount of 0.4 ft. per sec. more than they retarded the piece of wood. The latter not being wholly submerged may have been itself somewhat retarded. Taking the observations during both ebb and flow into account it is evident that the drift of foam under the action of a fresh breeze and short, steep waves was not more than 0.5 ft. per sec., that is 0.34 statute miles per hour. This is so small that the measurements which I obtained at sea may be discussed as they were obtained, for the slight drift of foam does not affect the conclusions to be drawn from the observations made in the voyages.

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§3. *On the Use of an Anemometer on Board Ship.*

In January and February, 1914, I made a voyage from Southampton to Colon and back. For this occasion, through the kindness of Dr. (now Sir W.) Napier Shaw, F.R.S., I obtained the loan of a Robinson anemometer from the Meteorological Office. The management of the R.M.S.P. Company were so good as to recommend my investigation to the commander of the ss. *Oruba*, on which I went out and returned and I have to thank the commander and officers, particularly Mr. A. Hernandez, Chief Officer, for facilitating my observations. I obtained a certain amount of evidence on the point which I set out to investigate, but the chief results were those relating to the action of swell to hinder the development of waves by wind.

On the passage out the anemometer was on the Marconi house aft, which was a good position at first when the wind was following, but later on was sometimes sheltered; and I have decided not to use the measurements taken on the voyage out, or until leaving Trinidad on the homeward voyage, when the instrument was mounted on the bridge and remained fully exposed throughout the voyage thence to Ushant. One day's measurements only of those taken on the outward voyage are included in the following discussion, a day when the conditions were so simple as to make serious error almost impossible, the wind being dead aft, the smoke drifting slowly straight ahead, and the anemometer fully exposed. It took me some time to become expert in the determination of the angle made by the smoke track with the ship's course, and it is partly for this reason that I make no use of the observations in the earlier part of the voyage. I was never able to measure accurately the angle made with the fore-and-aft Marconi wires by the smoke as it left the funnel, and further from the ship the smoke was often caught by an eddy and its track bent. I found, however, that the smoke cloud on the horizon kept station with us and gave concordant results. It has also the advantage of being unaffected by momentary variations in the direction of the wind. The only trouble was that our coal was too good, not making as much smoke as I wanted, so that I had to be on the alert for the times of firing when the fresh charge of coal gave enough smoke to make a dark cloud.

The speed of the ship being obtained from the day's run, a line is drawn proportional to this, and from it another of indefinite length at the angle made by the smoke track with the ship's course. Upon this line is marked off a length equal to the speed shown by the anemometer. This is the speed resulting jointly from the speed of the wind and that of the ship. All that remains to be done, therefore, is to draw the third side of the triangle joining the beginning of the line representing the ship's speed with the end of the line representing the speed recorded by the anemometer. The base of the triangle so drawn shows both the true speed and true direction of the wind. Table I. shows the result of the measurements taken on the homeward voyage between Trinidad and the day of passing Ushant. On the latter day observations were only taken in the morning before reaching Ushant and near the edge of the continental shelf, so that all measurements

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TABLE I.—THE AMOUNT BY WHICH VELOCITY OF WIND EXCEEDED THAT OF WAVE DAY BY DAY (IN STATUTE MILES PER HOUR).

Date.	Position.		Velocity of wind from direction of smoke and anemometer reading.	Velocity of wave from period determined from foam spots.	Excess velocity of wind over wave.	Velocity of swell from period determined by foam spots.	Relation between direction of swell and that of the waves and record of height of swell.
	Lat. N.	Long. W.					
1914.	° ′	° ′					
Jan. 2	44 55	12 34	20.2	19.6	0 6	—	No swell.
Feb. 18	Between Trinidad and Barbados.		16.4	15.2	1.2	29.5	Concurrent with the waves.
,, 19	15 22	57 1	23.6	21.1	2.5	29.9	Ditto. Height, 15ft. above water-line.
,, 20	18 33	53 0	20.4	16.5	3.9	28.7	Following, at less than 45°.
,, 21	21 52	48 43	21.9	18.6	3.3	29.9	Ditto.
,, 22	25 14	44 14	22.6	16.3	6.3	24.6	Ditto, with a long low swell meeting the waves at about 85°.
,, 23	28 38	39 18	19.0	15.9	3.1	46.4	Principal swell concurrent, and a long low swell meeting the waves at about 85°.
,, 24	32 2	34 13	Wind of	variable	strength.	45 0	Height, 15ft. above water-line.
,, 25	35 17	28 50	,,	,,	,,	44.6	
,, 26	38 37	23 11	16.4	10.4	6.0	39.3	Meeting at 45° or less.
,, 27	41 54	17 21	19 4	11.7	7.7	39.5	Meeting at 87°, height 12ft. above water-line.
,, 28 a.m.	45 17	11 23	20.2	12.3	7.9	47.4	Following at 82°, height 24ft. above water-line.
,, 28 p.m.	,, ,,	,, ,,	13.9	10.6	3.3	47.4	Following at 27°, ditto.
Mar. 1 a.m.	S.W. of	Ushant.	16.7	12.3	4.4	42.7	Following at 21°, height about 18ft. above water-line.

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throughout the voyage were taken in deep water generally not less than two thousand fathoms, and only between Trinidad and Barbados, the position on the first day of the homeward voyage, is the sea affected by considerable current.

§4. *Diary of the Observations Summarized in Table I.*

The measurement on Jan. 2 is important because it was definitely noted at the time that there was no meeting or crossing swell, neither was any following swell noted. This was the only day on the outward or homeward voyage on which no swell was recorded. The wind travelled at 20.2, the waves at 19.6 miles per hour. The excess of 0.6 miles per hour comes within the definition of a calm. Even if we allow 0.34 miles per hour for drift of foam, the speed of wind relatively to the wave is just below Beaufort's "force 1," the least which will give a fishing smack steerage way. Thus at the outset I had obtained a figure in accordance with the expectations I had formed. During most of the voyage, however, these expectations were by no means fulfilled, and the figures with which I returned home seemed to be quite irregular. Fortunately, however, I had recorded daily the size, speed and direction of the swell, and these provided the clue to the irregularity, as I shall presently show.

During Feb. 18 and 19 the waves and swell were precisely concurrent, and the swell was much the more conspicuous part of the disturbance. The speed of the wind on Feb. 18 exceeded that of the waves by 1.2, and on Feb. 19 to 2.5 statute miles per hour. On both days therefore the waves travelled in a "light air," Beaufort's "force 1," from 1 to 3 miles per hour, a condition in which a fishing smack just has steerage way and in which the direction of wind is shown by smoke, but in which the force is not sufficient to direct an ordinary wind vane. This remains true even if we add 0.34 miles per hour to the speed of the waves on account of drift or foam. It may be added in this place that but for the foam method of timing the separate undulations of the sea I should certainly have neglected to time the true wind waves on Feb. 19 and have mistakenly recorded the swell as the wind wave. The first description entered at the time in my observing book is "waves" and "minor inequalities" for the swell and the true wind waves respectively. Timing the rise and fall of the foam spots revealed the significance of the "minor inequalities" and showed them to be regular.

Anemometer readings are for an hour or more except two occasions of half an hour. On no single occasion are the waves recorded as exceeding this sustained speed of the wind, an anomalous result which hitherto has frequently appeared in the records even of experienced observers.

Throughout the next two days, Feb. 20 and 21, the conditions continued to be typical of the Trade Wind region. The swell retained about the same speed. On the 20th it was still the chief feature of the disturbance, but on the 21st had considerably diminished in height. On both days it followed and overtook the waves at an angle less than 45°. On these two days the speed of

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the wind exceeded that of the waves by 3.9 and 3.3 miles per hour, or between the " 1, light air " and " 2, slight breeze " of Beaufort's scale, enough to give a fishing smack steerage way, but barely enough to fill the sails.

On Feb. 22 the Easterly Trade Winds continued, still with about the same force as since leaving Barbados, a fresh breeze, and there was again a swell overtaking the waves at a sharp angle. Its speed was somewhat less than hitherto, namely, 24.6 miles per hour, but its character was obviously the same as that of the swell on the preceding days, namely, that resulting from the Trade Wind when blowing with somewhat more force than it possessed at the time of observation. A new phenomenon, however, appeared on this day, suspected in the morning, evident in the afternoon. This was a longer, swifter, flatter swell from a westerly direction, cutting the wind waves nearly at right angles. The arrival of this swell marked the approach to the northern limit of the Trades, the latitude at noon being 25° 14′ N. The difference between the speed of wind and wave on this day was no less than 6.3 miles per hour. On the 23rd there was again a long low westerly swell cutting the waves at nearly a right angle, but the easterly swell was precisely concurrent with the waves, and the difference between the speed of wind and wave was only 3.1 miles per hour.

On Feb. 24, latitude at noon 32° 2′, the wind was variable in strength, and no certain conclusions could be drawn as to relation of its velocity to that of the waves. The swell came from a little west of north and met the waves almost point blank. Feb. 25 was a day of light and variable airs and it was judged inexpedient to attempt a comparison of velocity of wave and wind since the latter was momentarily fluctuating. The swell continued to be from near the north.

On Feb. 26 in latitude 38° 37′ N. and for the remainder of the voyage, the wind was between north and west, the force varying from 13.9 to 20.2 miles per hour, as against a range from 16.4 to 23.6 miles per hour in the Trades. The swell on the 26th was opposed to wind and wave, meeting the waves at an angle of 45° or less, and the waves travelled 6 miles an hour slower than the wind. The swell on the 26th was not markedly higher than those of the 20th and 21st, and had a much greater wave length, so that it did not cut up the front of the waves so much.

The following day, Feb. 27, the swell crossed the waves almost at a right angle. On this and the remaining days of the voyage the direction of the swell could be determined with much greater accuracy than hitherto. On the 27th the angle was measured as 87° *meeting*. The swell was now higher than it had been on the 26th or 23rd. The waves were not only of small height but with very short frontage. The difference between speed of wind and wave was 7.70 miles per hour, the greatest so far recorded. There was much foaming and breaking where the wave was borne on the top of the swell.

On the morning of the 28th there was a very big and regular swell, twice as high as on the previous day, a height of 24 feet above the ship's flotation line being repeatedly measured, and the ridges apparently stretched uninterruptedly for more than a mile.

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The waves were again of small height and with short fronts. In the morning the swell cut them at 82°, but this time following instead of meeting. The recorded difference of velocity between wind and wave was 7.9 miles per hour, almost the same as on the preceding day. The velocity of wind was exactly the same (20.2 miles per hour) as on Jan. 2 when there was no swell. The excess velocity of wind over wave with no swell was 0.6 miles per hour, which is reckoned as a calm; with the big crossing swell 7.9 miles per hour, which is just about sufficient to make a smack begin to careen.

On the afternoon of the 28th the wind changed direction, so that the following swell crossed the waves at an angle of 27° instead of 82°, and the speed of the wave was only 3.3 miles per hour less than that of the wind instead of 7.9 miles per hour less as in the morning.

The steepest swell was on Feb. 19 in the Trade Winds when the length was 375 feet and the height above the ship's waterline was 15 feet. The full height of the wave from crest to trough would be greater, so that the swell was really steeper than the figures indicate. Taking them, however, as they stand the ratio of length to height would be 25 : 1. The average slope corresponding to this is 1 in $12\frac{1}{2}$, or $4\frac{1}{2}°$. The highest swell was on Feb. 28, 24 feet above waterline. As this swell was much longer than the ship, the full height from crest to trough would differ by a smaller fraction from the height above waterline. The length, which was also the greatest recorded on the voyage, was 943 feet, so that the ratio of length to height was rather more than 39 to 1, with an average slope of 1 to $19\frac{1}{2}$, an angle a little less than 3°. The waves of Feb. 27 had a wave length of 57.5 feet. They were insignificant in appearance on account not only of their small height, but of their short frontage and of some irregularity of direction. It was impossible to measure their height, but the officer of the watch and I agreed that they did not appear to be more than one and a half feet.

In the following Table the observations are re-grouped according to the direction of the swell relatively to the waves.

§5. *General results as to the effect of swell to hinder the wave-making action of wind shown in Table II.*

There were days on the voyage when the swell rose above the point of sight either on deck or at port holes, but the wind waves were never high enough to measure in this way, and their height could only be judged from the surroundings and from recollection of other seas. I have no doubt, however, that the height of the waves on this voyage when the swell was throughout the dominant feature was always much less than that produced by wind of the same velocity in absence of swell. In connection with the latter condition I recall in particular the steep waves of considerable height and regular frontage formed in the Red Sea by a northerly breeze blowing parallel to the coasts. The speed of the wind was only 14 statute miles per hour, as was known from the circumstance that the air on deck was completely stagnant when the vessel was steaming at this speed in the same line as the wind.

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TABLE II.—DIFFERENCES OF SPEED BETWEEN WIND AND WAVE, GROUPED ACCORDING TO DIRECTION OF SWELL.

Direction of Swell.	Character of Swell.	Date of observation.	Amount by which speed of wind exceeded that of wave.	Average difference of speed in statute miles per hour.
Concurrent with waves	High, quick period, slow progression	Feb. 18	1.2	1.85
		,, 19	2.5	
Following the waves obliquely	Quick period, slow progression	,, 20	3.9	3.725
		,, 21	3.3	
	Slow period, quick progression	28 (p.m.)	3.3	
		Mar. 1	4.4	
One concurrent, one at right angles	That at right angles very slight	Feb. 23	3.1	3.1
One following obliquely, one at right angles	That at right angles very slight	,, 22	6.3	6.3
Swell at right angles, or meeting obliquely	High, with slow period and swift progression	,, 26	6.0	7.2
		,, 27	7.7	
		28 (a.m.)	7.9	

It is also instructive to compare the waves made by a fresh breeze when kept short by a crossing swell with those under the same force of wind when kept short by the neighbourhood of a windward shore. In the former case the slope of the waves is very slight, in the latter there is a steep sea.

The observations on Feb. 18 and 19 show that when swell and wave are concurrent the chief effect of the swell is to diminish height, the reduction of speed being small. The records of crossing swell show, on the contrary, considerable reduction in the speed of the waves. Of these records four relate to a single set of crossing swells which followed and overtook the waves at a sharp angle, three to a single set of swells which either advanced to meet the waves or cut them squarely. The deficiency in the speed of wave as compared with speed of wind was about twice as great under the latter conditions. The average speed of the wind itself was the same in both. On each of the two remaining days of observation there were *two* sets of swell. On Feb. 23 when the following swell was concurrent with the waves the speed of wave was 3.1 miles per hour less than that of the wind, in the other case when the following swell crossed the waves at a sharp angle the deficiency of the waves speed was 6.3 miles per hour. The second set of swell which crossed the waves squarely was of very small height, the following swell only moderate, and taking these facts into account, the indication of the two days is that when two sets of swell cross the waves their respective effects in reduction of wave are strictly additive.

On the morning of Feb. 28 the height of the swell was twice as great as on Feb. 27, but the retardation of the waves was scarcely

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increased. Interference was at somewhat longer intervals on the second day, but, even if considerable allowance be made for this, it seems fairly clear that doubling the height of swell has less effect in reducing the waves than the presence of a second set of crossing swells. The records show that the effect of a crossing swell which has to catch up the waves is much less than that of swell which approaches at a right angle or from an opposing direction, but it is not possible to decide from the observations so far obtained what proportion of the effect is due to greater swiftness of encounter and what proportion to greater frequency of encounter.

These observations suggest that the rapid rise of waves upon large lakes and enclosed seas is not entirely due to sudden development of strong wind, for here there is little residual swell to hamper the wave-making action of wind. On the other hand, when wind gets up on the ocean it generally blows across the swell, for the direction of the wind works round as a storm develops and the principal swell left by the last storm seldom has the same direction as that of the wind at the beginning of the next storm. On the relatively rare occasions when it comes on to blow hard in the direction of a great swell left by the last storm the waves no doubt grow even more rapidly than on enclosed seas, as happened in the storm in the Bay of Biscay to which reference was made at the beginning of the paper.

§6. *On the dynamical action of the Swell upon the Wind.*

Observation suggests that the dynamics of the action of swell upon wind is as described in the following paragraphs, but the author must leave the decision as to the validity of this explanation to those who can apply the methods of hydrodynamics to the data.

Let us first recall the final condition in the open sea when waves have attained full development and there is no noticeable swell. The waves are not perfectly equal in length, nor are their ridges perfectly straight, but the general pattern does not change as time goes on, so that, I presume, it is possible for the flow of the air above to be so nearly conformable with the march of the waves below that the forces applied to the latter have a rhythm which tends to reinforce the waves, not to damp them down. Suppose, next, that there is a considerable swell running in ridges parallel to those of the waves. The change in the form of the water surface would not be very conspicuous in an instantaneous photograph but very striking in a cinematograph, for the pattern is changing all the time. If the swell be following, the pattern changes slowly and the flow of air is only disturbed gradually. If, however, the swell and waves meet in opposing processions the pattern of the ridges on the water goes through its gamut of change very rapidly, and anything approaching a steady flow of air is consequently impossible.

When the procession of the swell crosses the procession of the waves the fronts of the latter are cut up, and this must introduce a horizontal circulation in the air which cannot but hinder wave-making, for this process is associated with undulation in the vertical plane and (when the waves are steep) with eddies having their axes horizontal.

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§7. *On the Effect of Crossing Swells to introduce Errors in the Estimation of Force and Direction of Wind at Sea.*

One day in the course of a voyage from Colon to Southampton, in 1912, when I was on the bridge with the Commander, a seaman of long experience, I asked him to estimate the force of the wind on Beaufort's scale. He put it at number 2, that is to say, 5 miles an hour. The speed of the ship through the water was 15 knots, with an opposing tide. Her true rate of progression must have been at least 13 knots, that is to say, 15 statute miles an hour. The wind was dead aft and steady, and the smoke was rising absolutely straight up from the funnel, so that the real speed of the wind could not have been less than 15 statute miles an hour. The waves were not only low but irregular with short frontage. I recorded at the time a long, low, following swell cutting the waves at about 75°. The measurements obtained during the voyage of 1914, when I was provided with an anemometer, show that the slightness of "the sea" on this occasion was due to the crossing swell, and it was upon the slightness of the wave disturbance that the commander based his erroneous estimate. There were other days when the wind followed the ship's course more or less directly during the fine weather voyage of 1912 on which I found the officially logged number for wind velocity much too low to reconcile with the indications of the smoke cloud.

During the voyage of 1914 I found that crossing swell is also a source of error in the records of wind direction at sea. The direction of the waves is the same as that of the wind, but when the observer tries to judge the direction of the waves from their general run he often finds it difficult to make up his mind as to the exact direction on account of irregularity. When, however, a wave curls over and breaks in foam the direction of breaking is definite and easily observed, and this is often recorded as the true direction of the wind. I observed that when there was a diagonal swell the direction of breaking was intermediate between the course of the waves and the course of the swell. On three days when the swell was nearly at right angles to the waves the average deflection of the breaker was only $2\frac{1}{2}°$, but on five days when the swell crossed the waves at an angle between 20° and 45° the average deflection was $14\frac{1}{2}°$.

The observations on this voyage afford also a strong indication that the line of the foam bubbles is influenced by the direction of breaking, for I repeatedly found it to be intermediate between the direction of the swell and that of the wind aloft as determined by the three observations, direction of smoke, speed of ship and anemometer reading.

The errors in estimation of velocity and direction of wind introduced by crossing swell are large during fine weather, but if the wind blow hard and steadily until the swell is a subordinate feature, both the curl on the wave and the line of foam spots will, no doubt, be closely concordant with the true direction of the wind.

On this voyage, however, the swell was usually the larger part of the sea disturbance, and I have thought it best not to use the observations of direction of foam bubbles and gulf weed for deter-

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mination of wind direction but to rely on the smoke track and anemometer reading.

APPENDIX (February 17th, 1926).

The range of velocity of wind on the only voyage when I had the use of an anemometer was too small to indicate whether the final relation of velocity of wave to wind in absence of crossing swell approximates to constant difference or constant ratio, but when the results are combined with the observations on Dec. 29th, 1898, and Dec. 21st, 1911, the indications are towards an approximately constant ratio of about 9/10. As, however, the values for strong winds were only estimates, more numerous observations are required before certainty can be attained.

When hove-to in the storm of Dec. 21st, 1911, I found that waves which, as seen from the passenger deck, had an apparent length of 200 feet were in fact 600 feet in length,[3] and from the experiences of this memorable day I reached the conclusion that breakers with a period of 19 seconds, such as I recorded on Dec. 29th, 1898, may have been the principal waves of the storm and not, as suggested in my book on *Waves of the Sea*, published in 1910, a long "swell" rendered inconspicuous by shorter, steeper and perhaps higher waves. "Swell," pure and simple, is, I believe, the proper term for undulations progressing under the action of gravity alone, the "free" waves of the mathematician. The waves proper of the sea are those which owe their special form and certain other characters to the wind which is blowing at the time, but are never wholly "forced" waves, and when of any considerable length and speed obtain their energy largely by gravitational transmission over long distances, as is indirectly attested by the fact that they are not produced near a windward shore. "The velocity attained by the wind during a storm" means, in the customary language of science, the highest average maintained for one hour, during which time the velocity may vary repeatedly in the proportion of about 1 to 2. Thus, if the waves be travelling with, say, 9/10 "the velocity of the wind" they are alternately accelerated and elevated, retarded and depressed, and the favourable balance is sufficient to counteract the waste of energy due to friction or turbulence. Thus, perfect precision of statement cannot be attained when speaking of the relation of velocity of wind and wave, but the limit of recorded period of breakers, and the limit of wind velocity maintained for minutes in squalls and for seconds in gusts, have a concordance which indicate that the relation can be profitably studied. Thus, the sequence of 139 breakers with a speed of 66.4 m.p.h., which occupied 45 minutes in arrival on the afternoon of Dec. 29th, 1898, were preceded in the morning by five short sets of breakers with an average speed of 69.5 m.p.h. spread out over a period of 52 minutes. The length of each group in deep water was from rather more than 1 mile to 2½ miles, their time of arrival 1 to 2 minutes. Thus, they seem to be groups of waves pushed to greater speed during the squalls of the storm, and to have outrun the rest of the waves. A speed of 78.5 m.p.h. was recorded for a group of 12 breakers on Feb. 1st, 1899, the period being 22.5 seconds, the wave length 2,560 feet, *i.e.*, very nearly

[3] For details see *J. Roy. Soc. Arts.*, Nov. 1st, 1912, p. 1110.

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half a mile. But if momentary gusts of 100 m.p.h. produced groups of conspicuous waves we should presumably have seen breakers during this stormy winter of about 25 second period (speed 87 m.p.h.) and nothing in any way approaching this was recorded. Want of space would account for their not being formed as well as want of time, for whereas a four minutes' squall advancing 30 m.p.h. would *cover* four waves of half-mile length, a momentary gust during this squall would only cover part of one such wave.

What is required now is observation at sea upon the rate of change in the speed of waves following change in velocity of wind.

DISCUSSION.

Dr. G. C. SIMPSON said he was very interested in listening to the work as a whole, but he was a little bit doubtful, he would not say suspicious, about the agreement between the wind and the velocity of the waves. It seemed too good to be true. The anemometer which was used in this work was probably 50ft. above the sea. When the sea is rough there must be a considerable difference in the velocity at 50ft. and at the surface, and probably it was the surface wind which had affected the waves and therefore the difference of only 2 or 3 m.p.h. was very difficult to understand. He would like to know for how long the observations of the wind were taken, and what was the amount of the wind for an hour; because the waves must take some considerable time to get to a maximum and to die down, and he thought they could never agree with the mean velocity for a short period. There is one remark which is rather off the subject of the paper, but he would like to make it. Had the author any idea why it is that at sea, when a heavy rain shower occurs, the sea, with no change of wind, immediately should flatten, leaving simply the swell and no waves at all? What happens in that case?

Captain Sir DAVID BARKER said anything which Dr. Vaughan Cornish has to say about waves is listened to with attention. He (the speaker) had paid particular attention to this subject, and he was sorry Dr. Cornish had had no experience of a long sailing-ship voyage, for in that case he might have modified his views. He could not agree that there was a marked ratio between the speed or force of the wind and the speed or height of the waves, speaking generally. The wind was variable, and often in the height of a storm the wind force would drop, leaving the ship (sailing) in great danger of being "pooped." The sea was not variable in this way. At times the wind blew with such force that it raised waves in the waves and even blew off the tops of the waves, filling the air with sea-spray as high as the mastheads (170ft.) and making the outlook very misty. This was uncommon, and he (the speaker) only saw it in the southern oceans. He thought Dr. Cornish should make it quite clear what he meant by the height of a wave above "ship's flotation line" and also "above waterline." He quite agreed with Dr. Vaughan Cornish's remarks as to the difference in appearance of the sea from the bridge and from the main deck. It was constantly the habit at sea to record what the wind felt, not actually what it really might be; but a sailor can tell instantly the true direction of the wind from the curl of the sea; he does not want to think it out. He (the speaker) welcomed the paper as an interesting addition to an important subject.

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The PRESIDENT (Sir Gilbert T. Walker, F.R.S.) said his chief difficulty in this matter was to understand how the swell with the very large velocity which it possessed could arise out of the comparatively small velocity that the wind exhibited.

Commander L. G. GARBETT, in a written communication, said that Dr. Cornish in the last section of his paper refers to errors in the estimation of wind force due to "cross swells," and quotes a case when he asked the commander of a ship on which he was travelling for an estimate of the force of the wind on a particular occasion. It is difficult to understand how any seaman of the experience of the commander quoted by Dr. Cornish could have estimated the force of the wind as 2 on the Beaufort scale under the conditions mentioned in the paper. The ship was said to be going 13 knots (15 m.p.h.), the wind was aft and the smoke was rising vertically, and therefore whatever the appearance of the sea might be, it would, I am sure, have been obvious to the majority of seamen, as it was to Dr. Cornish himself, that the force of the wind must have been 4 on the Beaufort scale, *i.e.*, in m.p.h. the same as the speed of the ship.

The average seaman, in estimating the force of the wind at sea, does not go by the appearance of the sea alone, as Dr. Cornish appears to think, but takes into consideration the effect of the wind on his surroundings generally; also, on account of his constant exposure to all winds and weather, he acquires a sort of instinct which we call "sea sense" which enables him readily to estimate the force of the wind on Beaufort scale with a considerable degree of accuracy even in cases when there is a cross swell.

It is true, I think, that British seamen are inclined to record wind force as being less than it really is, especially when the wind is high, but I cannot believe from my own experience that the majority of seamen under such definite conditions would make such an inaccurate estimate as quoted.

Dr. H. JEFFREYS, in a written communication, commented on the great value of quantitative observations of wave motion, such as Dr. Cornish has made in very great numbers. Those who try to discover the reasons for natural phenomena are continually handicapped by the absence from the descriptions of eye-witnesses of the essential points required to test any theoretical explanation, and Dr. Cornish has done a most important work in devising methods for such observation and carrying them out with such care.

It is not very clear how the wave velocities in some cases have been computed from the observed periods. The formula ordinarily given assumes the waves to be two-dimensional, which is often not the case. If the wave is a three-dimensional one, the form of the free surface being given by

$$\zeta = a \cos(\kappa x - \gamma t) \cos \kappa' y$$

and we put

$$(\kappa^2 + \kappa'^2)^{\frac{1}{2}} = \mu\kappa$$

The wave velocity is γ/κ, and is easily found to be equal to $\mu g/\gamma$. For two-dimensional motion μ is unity, but if the distance between consecutive points of maximum elevation, measured across the direction of propagation, is comparable with the corresponding distance measured in the direction of propagation, μ may be as great as 1.4. In ordinary cases it does not seem impossible that the velocity of three-dimensional waves,

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calculated from the period on the assumption that they are two-dimensional, may be too low by 20 per cent.

Dr. VAUGHAN CORNISH, in reply to Dr. Simpson, said the anemometer readings referred to periods of one hour or more except on two occasions when the period was about half an hour.

The wind close to the wave-water is a series of travelling eddies, and immediately above it is probably a switchback. He supposed that if the average speed of the straightforward wind above the switchback, as maintained for an hour, be greater than the speed of the waves, the wind would tend on the whole to raise the waves and to push them along. The waves with which the wind has to deal are largely "swell" in the sense that the period of heaving of the water at any spot is largely due to gravitational transmission. It is consequently only at a great distance from the windward shore, where the selective action of transmission has had space to take effect, that a strong wind can find gravitational waves of nearly its own speed upon which to work.

The action of rain in flattening short waves whilst leaving the longer almost unaffected was the subject of a paper by the late Professor Osborne Reynolds, F.R.S. He showed that the rain-drop drove a vortex of salt water downwards, thus tending to annul the rhythmic movement of such waves as only affect the water to a small depth.

With regard to Sir David Barker's remarks, the contention in the paper is not that there is a definite relation of speed of wind to speed of wave under all conditions, but only under the condition of the final state attained under a prolonged wind. If the statement that a sailor can tell instantly the true direction of the wind from the curl of the sea means that the direction of the curl is readily determined, he agreed; for, indeed, the observation requires very little practice; but the contention is that the identity of the direction with that of the wind is open to question and cannot be substantiated in face of measurements.

With regard to the point raised by the President that the observed excess of average speed of wind, as maintained for about an hour, over that of the swiftest undulation seems very small when we think of the great amount of energy in such waves, we had to remember that it is these very long waves which are so slow to die down after a storm. He supposed that any one of them which is receiving energy from a great number of its fellows behind only needs to absorb enough energy from the wind to counteract a loss from friction and other causes.

Commander Garbett contends that the officer who made the erroneous estimate of Beaufort number quoted in my paper was probably an exception among seamen; in point of fact, however, his estimates of these numbers during the voyage were not discordant with those of the other officers of the ship. On several voyages he had worked on the bridge in co-operation with officers charged with the duty of making these observations and found among them men possessing the scientific spirit who welcomed measurement as a desirable supplement to "sea sense," and regarded the research on which he was engaged as applicable to seamanship as well as to meteorology.

In reply to Dr. Harold Jeffreys, he said that the velocities were calculated from the period by the ordinary formula for a two-dimensional wave. The observations on December 21, 1911, are not consistent with a theory which would add 20 per cent. to the velocity of the wave. He believed he was right in saying that Dr. Jeffreys regarded *swell* as

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two-dimensional. The principal inequalities travelling in the direction of the wind during a gale are largely of that character, and the bow-fronted ridges often seen produced by the impact of the wind upon the surface of the water contain only a very small part of the energy of the sea disturbance.

The Aurora Borealis.

A brilliant display of the Aurora Borealis was observed at Larkhill from 19.30 until 19.39, and again from 19.55 to 20.03, on March 9, 1926.

The phenomenon first appeared as about three dim, white rays extending from the horizon upwards, the light gradually becoming more intense, and the number of rays also increasing. These rays were all parallel to each other, and at first were inclined from the horizon to the left, making an angle of about 70 degrees with the horizon. The display first appeared in the NW, and after a short while this portion of the sky assumed a flame colour (as might be seen reflected in the sky during a great fire). Through this the strongest white rays could still be seen penetrating, increasing and diminishing both in length and in width, and the intensity of light varying rapidly. It was noticed that the rays were the same width throughout (*i.e.*, between base and apex). Finally, the area divided into two sections, one being to WNW and the other to NNW. The elevation of the Aurora varied from 25 to 35 degrees, and eventually the display gradually disappeared.

The second manifestation was rather more brilliant than the first, and concluded by fading into a phosphorescent glow to the North.

The phenomenon was observed by many in the same locality, and extensively over a wide area of Great Britain.

The following weather observations were taken during the time of display :—

Cloud.—First occurrence : The sky was clear but for 1/10 cloud (St. Cu.) to the right of luminary.

Second occurrence : Sky clear but for 1/10 cloud. Small patches of Fr. Cu. moved from left to right across the illuminated area.

Visibility.—Horizontally, good. Vertically, good.

Temperature.—Around 40° F.

Humidity.—Around 72 per cent.

Wind.—Velocity, 15 m.p.h. Direction, from WNW.

The pressure distribution was high from North of the Azores to France, and very low off North-West Norway and Iceland. Over the British Isles, isobars were comparatively straight.

P. Raymond Zealley.

Meteorological Office, Larkhill.
March 13, 1926.

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ADMIRAL SIR FRANCIS BEAUFORT AND THE BEAUFORT SCALES OF WIND AND WEATHER.

By Commander L. G. GARBETT, R.N.

[Received December 8, 1925.—Read February 17, 1926.]

The Beaufort Scales of Wind Force and Weather Notation need no introduction to Fellows of this Society—they are in general use by nearly all the Meteorological Offices of the world and have been used by seamen for nearly a century.

Francis Beaufort (afterwards Admiral Sir Francis Beaufort, K.C.B., F.R.S.), the designer of these Scales, was a remarkable man, and it may not be out of place to recall briefly a few of the chief events of his distinguished career.

Beaufort was born in Collon, Ireland, in 1774, and entered the Navy in 1787. He saw much active service afloat in the early years of his career and took part in the memorable action of the 1st June, 1794, off Brest. In October, 1800, he distinguished himself in a boat expedition by capturing a Spanish vessel, the *San Josef*. Beaufort himself received no less than nineteen wounds and was promoted to Commander for his gallantry. In 1805 he was given command of H.M.S. *Woolwich*. During the three years he was in this ship he covered the great distance of 60,000 miles and it was during this period that he drew up the scales of wind force and weather notation which bear his name.

In 1809 he was selected to take charge of the important survey of the coast of Karamania, a little known portion of Syria. This he continued until 1812 when he was very severely wounded by a party of Turks and was thereby prevented from carrying out any further service afloat. The result of his work was not only an accurate survey, from which he produced a set of charts, the like of which had never been seen at the Admiralty before, but a historical review of the country. Beaufort's *Karamania*, published in 1816, was the book of the day and was said to be superior to any of its kind in whatever language, and one which passed triumphantly through the ordeal of criticism in every nation in Europe. In 1814 he was made a Fellow of the Royal Society.

During the following years Beaufort employed his energies in connection with many scientific studies and in 1829 was appointed Hydrographer of the Navy, which important post he held with eminent success for 26 years.

He was one of the founders of the Royal Geographical Society and was also a Fellow of the Royal Astronomical and Geological Societies, a D.C.L. of Oxford and honorary member of many foreign societies. He died in December, 1857, at the age of 83, only two years after his retirement as Hydrographer of the Navy. He was always a keen meteorologist and he continued to keep a meteorological log after he left the sea and did so up to within three weeks of his death.

The following extract from an obituary notice which appeared

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in one of the leading London papers is of interest as it gives an idea of the great esteem in which he was held:—

> "No pressure of national interest or calamity should preclude any of the honours due to the memory of such a man as Admiral Sir Francis Beaufort, who was not only a priceless treasure to his country but a benefactor to the world. Wherever science is cultivated there Francis Beaufort is honoured. The contemporary of a great band of philosophers, in a scientific age, he held a prominent place among them and was revered by them all, be they who they might."

In order to investigate the development of Beaufort's Scales of Wind Force and Weather Notation, a large number of logs kept by him, both officially and privately, from the year 1790 onwards, have been examined. No records have been traced for the years 1812-1820, and from 1820 to the time of his death he appears to have kept meteorological logs independently of his private logs. They are all, whether official or otherwise, kept with exceptional care and neatness, and as he gained experience of the sea, his increasing interest in all matters concerning the weather is apparent. As a midshipman we find him at first making only a short general note of the wind and weather each 24 hours, and but a few years later a descriptive account of the weather conditions is often given every two hours and he begins occasionally, too, to forecast the probability of changes with much success. The private logs kept at sea up to 1812 are bound in vellum and are in a very fine state of preservation. They are full of interesting information bearing upon every aspect of life in the navy in those days. A few extracts from the logs are given below in order to give a general idea of the nature of the contents in so far as they refer to the weather.

On November 26, 1806, he writes:—"Threatening dark appearance, but in exact conformity to the Toricelli oracle it soon ended in smoke. 'Whatever may be the merits of this instrument in high latitudes it is certainly useless between the Tropics many intelligent men have pronounced.' I take leave, however, to think the reverse and that its variations though not so distinct are equally precise."

On December 12, after describing how the whole fleet had been caught aback by a very violent gust of wind with a deluge of rain and horrid flashes of lightning, he continues, "at daylight the squall had abated, observed the fleet none without damage except God be thanked this ship. In this region (Lat. 30° 42′ S., Long. 38° 32′ E.) I never trust a Northerly wind drawing to the westward with haze. Unfortunately I missed looking at the Barometer in the scurry so I don't know how it agreed with the wind."

On February 8, 1808, he writes:—"This morning at sunrise a very bright white rainbow, or corona, or halo, I don't know which to term it, appeared on the opposite side of the heavens. It was about 3° broad, rather a reddish-brown on the external view, dense cloudy white in the middle, browny muddy and dull on the inside where it was bounded by a dark black circle. Two inner

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concentric circles affording the same appearance but much fainter were about 6° asunder. Sometimes when the sky became cloudy it disappeared and was brightest when the sky was all blue, at least a vapoury whitish blue, for it was now quite clear. This continued sometimes visible, sometimes obscured till three in the afternoon when it became cloudy."

The remarks on a waterspout on August 9, 1808, are of interest. "A squall came in in the shape of a whirlwind, it did not last 10 seconds of time, but for that period laid the ship on her

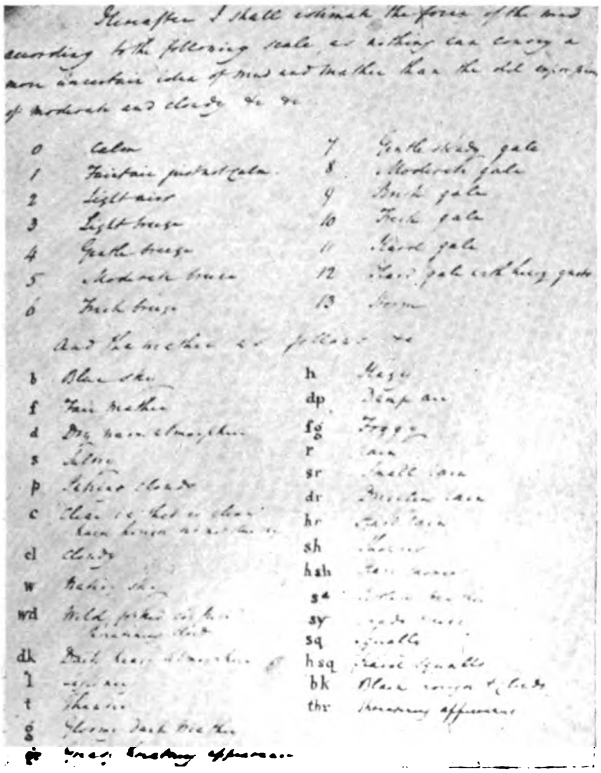

FIG. 1.

(The original sheet is twice this size.)

beam ends—the ship was enveloped in a kind of spray though the sea all round was in a violent agitation and as it passed off to leeward, a column of water ascended from the sea about half the height of the maintop."

The first mention of Beaufort Scales of Wind Force and Weather Notation are to be found in his private log of 1806 and the facsimile of the page facing January 13 is produced in Fig. 1.

From 1806 onwards he used these scales, modified from time to time, in his private logs and the particular scales in use in each log are inserted on the first page in his own handwriting.

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Columns are ruled on each subsequent page, in which he notes the wind direction, the appropriate figure for the force of the wind and the letter denoting the weather, and this method of recording has been followed in the Admiralty logs up to the present day. The scales do not appear to have been used anywhere but in his private logs up to 1838, as there is no mention of them in the official logs of H.M.S. *Woolwich* or in any of the official logs of other ships in which Beaufort served, nor was I able to find any mention of them in any official logs of H.M. ships prior to 1838. From this it is clear, I think, that the scales were not in general use at sea prior to that year.

The first printed reference to them is to be found in the *Nautical Magazine* of 1832 in an article entitled, "The Log Board." This article definitely ascribed the formulation of these scales to Admiral Beaufort and recommended their adoption for general use. It may further be noted that the scale discussed in the article contained the last revisions made by Beaufort himself. These were the scales which were officially introduced into the navy in 1838 as recorded in a *Memorandum* issued by the Admiralty in that year. A copy of this *Memorandum* is given in Fig. 2. This scale is still in use in the navy to this day with only very slight modifications.

These scales were adopted in the Mercantile Marine somewhat later, and the first Board of Trade publication to mention them was the *Barometer Manual* of 1862.

Wind Scale.

Firstly, to discuss the wind scale. It is worthy of note that designations for winds of different strengths were in common use at sea at least for half a century before Beaufort introduced his scale. In a publication dated 1769, entitled, *An historical account of the Great Storm of* 1703, the following designation of wind is given with notes appended:—

Stark calm.	A topsail gale.
Calm weather.	Blows fresh.
Little wind.	A hard gale of wind.
A fine breeze.	A fret of wind.
A small gale.	A storm.
A fresh gale.	A tempest.

In pointing out the contrast between what a ship could stand in his time 1769 and in 1703 the writer of the book makes the following remarks:—

> "What our sailors call a topsail gale would have driven the navigators of those days into harbour. When our hard Gale blows they would have cried a tempest, and about the Fret of wind they would be all at their prayers."

It should, however, be noted that no numbers are allocated to these terms. Beaufort's original scales of 1806 contained in addition to calm, 13 degrees of wind force. The scale was modified in 1807 by unifying faint air and light air and calling this Force 1, light air, and thereby reducing the scale to 12 specifications of wind force in addition to calm.

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Admiralty, Dec. 26th, 1838.

MEMORANDUM.

THE Lords Commissioners of the Admiralty having had under consideration the general utility of recording with clearness and precision, in the Log Books of all Her Majesty's Ships and Vessels of War, the actual State of the Winds and Weather, have thought fit to order that henceforward in each page of the Log Book two columns should be introduced, wherein the force of the Wind and the appearance of the Atmosphere shall be every hour registered according to the annexed scheme, a copy of which shall be pasted into each book, and painted on the back of every Log Board or Log Slate; and two more columns shall likewise be given for the purpose of entering the heights of the Barometer, or Sympiesometer, and Thermometer, when such instruments may be on board.

By Command of their Lordships,

C. WOOD.

To all Captains, and Commanding Officers of Her Majesty's Ships and Vessels

FIGURES
TO DENOTE THE FORCE OF THE WIND.

0	denotes Calm.		
1	Light Air	just sufficient to give	Steerage way.
2	Light Breeze	With which a well-conditioned man-of-war, under all sail, and clean full, would run smooth water, from	1 to 2 knots.
3	Gentle Breeze		3 to 4 knots.
4	Moderate Breeze		5 to 6 knots.
5	Fresh Breeze	In which the same ship could just carry close-hauled	Royals, &c.
6	Strong Breeze		Sm. low-crs'd sail top-gallant sails.
7	Moderate Gale		Double-reefs, jib, &c.
8	Fresh Gale		Triple-reefs, courses, &c.
9	Strong Gale		Close-reefs, & courses.
10	Whole Gale	with which she could only bear	Close-reefed main top-sail and reefed fore-sail.
11	Storm	with which she would be reduced to	Storm stay-sails.
10	Hurricane	to which she could show	No canvas.

LETTERS
TO
DENOTE THE STATE OF THE WEATHER.

b	denotes Blue Sky—whether with clear or hazy atmosphere.
c	Cloudy—i. e. Detached opening clouds.
d	Drizzling Rain.
f	Fog—f Thick Fog.
g	Gloomy Dark Weather.
h	Hail.
l	Lightning.
m	Misty or Hazy—So as to interrupt the view.
o	Overcast—i. e. The whole sky covered with one impervious cloud.
p	Passing Showers.
q	Squally.
r	Rain—i. e. Continuous rain.
s	Snow.
t	Thunder.
u	Ugly threatening appearance in the Weather.
v	Visibility or Distant Objects.—Whether the sky be cloudy or not.
w	Wet Dew.
*	Under any letter denotes an Extraordinary Degree.

By the combination of these letters all the ordinary phenomena of the weather may be recorded with certainty and brevity.

EXAMPLES.

b c m.. Blue sky, with detached opening clouds, but hazy round the horizon.

g v.. Gloomy dark weather, but distant objects remarkably visible.

q p d l t.. Very hard squalls, and showers of drizzle, accompanied by lightning with very heavy thunder.

FIG. 2.

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In order to assist others to estimate truly the wind on this scale Beaufort in 1807 added a description to his scale numbers in terms of the speed at which a ship might travel or the canvas she could carry under certain conditions. In later statements of his wind scale found in his logs there is no important change in the names of the different forces 1-12, but in comparing them it is noted that in 1820 Beaufort revised his estimates of the speed at which a ship could travel with winds of Force 2 and 3.

Beaufort's frequent entry of halves in his logs kept at sea (*e.g.*, Force 6½) emphasises very strongly his confidence in his ability to estimate wind force with great accuracy.

Beaufort's original scale specified for a full rigged frigate of the early nineteenth century, but the introduction of double topsails about 1850 led to modifications to the scale which were suggested by the Maritime Congress in 1872 and confirmed by the Congress held at the Meteorological Office, London, in 1874.

There have been many subsequent changes in the rig and tonnage of sailing ships and, in particular, sailing ships have been almost entirely replaced by steamships, so that Beaufort's method of specification ceased to have its original meaning. The use of a Beaufort scale 0-12, however, has persisted at sea, but its usage has been handed on by tradition rather than by the use by individual observers of Beaufort's method of specification. In spite of this, however, there is a remarkable uniformity in the estimates which sailors make, at least in the Navy, of the force of wind at any given time.

As a result of long investigation a new specification has been adopted allotting to each number on the scale its equivalent in average velocity in statute miles per hour. The most important change in this specification, so far as seamen were concerned, was the modification of Force 7 from a gale to a strong wind. The late Captain Hepworth, in discussing this, said, "A good deal of time might be spent in arguing whether or not a moderate gale is really a gale in a seaman's judgment without coming to any satisfactory conclusion, but when it is necessary to draw a distinction for statistical purposes the implied contradiction of a moderate gale is unsatisfactory and for meteorological purposes a gale means a wind of Force 8." As the present specification, which was introduced in 1906, was fully discussed in a paper read before this Society in that year and also in meteorological publications, particularly *The Beaufort Scale of Wind Force*, by Dr. Simpson, it is not necessary to discuss the details further in this paper.

Beaufort Notation.

The consecutive revisions of the scale of Weather Notation, originally compiled in 1805 and modified from time to time up to 1832, which are shown in detail in Table I. opposite, are remarkable in one feature, they all tend in the direction of simplification of the symbols, so much so that the original scale of 29 symbols, of which 16 contain two or three letters, is finally reduced to 17 symbols, each of one letter; and there is little doubt that Beaufort regarded each change as a distinct improvement.

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TABLE I.—BEAUFORT'S WEATHER NOTATION

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Of the 29 symbols in the original scale, only five, b, blue sky; g, gloom; l, lightning; r, rain; t, thunder, still retain their original meaning. But c originally denoting "clear hard horizon, not blue sky," now indicates "cloud"; f, which originally denoted "fair weather," now means "fog," while p, originally "passing clouds," now indicates "passing showers." Others of the Notation such as hsh, indicating "hard showers with threatening appearance," no longer appear in the scale.

The attempt made in 1820 to introduce symbols in the scale to denote type of clouds was abandoned when the modified scale was introduced in 1826. It was in this latter year that the scale became entirely a one-letter scale having 17 notations (Fig. 2). In the earlier scale, when combining two or more of the notations, it was necessary to separate them by a . (dot) or a — (dash), *e.g.*, c.cl—s = clear atmosphere, cloudy and hard squalls; whereas in the final form of the scale as introduced by Beaufort all the ordinary phenomena of the weather may be expressed with facility and brevity by a combination of the letters and he gives as an example, qpdlt, meaning "very hard squalls and showers of drizzle accompanied by lightning with heavy thunder," a dot under a letter denoting an extraordinary degree. The single letter scale is in use in the Admiralty logs of to-day, and with very slight modifications shown in the last column of Table I. is also used in the Meteorological Office, Air Ministry.

From a careful study of Beaufort's logs it has been possible to obtain a more definite interpretation of certain letters whose interpretation was not otherwise obvious. In the earlier logs "b" was nearly always used in combination with "c," meaning "blue sky with clear hard horizon," and in his log of April 17, 1806, he records "bc," "beautiful clear sky, heavy bank of cloud to the NW"; it will be noted that "cl," meaning "cloud," is not used in this case. When in 1826 the interpretation of "c" was changed to denote "detached clouds," Beaufort added the note "whether clear or hazy atmosphere" to his symbol "b," and thereafter he frequently used "b" singly; in some cases at least "b" was used to denote "blue sky" when the dome of the sky was clear, independently of whether there was cloud low on the horizon or not. For detaching opening clouds "c" is often used alone in Beaufort's logs, and in 1834 there is an entry "c—bc," meaning "cloudy early, blue sky, clouds later," which seems to show that Beaufort used "c" when the sky appeared to be covered with clouds of some definite formation, probably clouds at different levels covering the sky. In the log of the sailing ship *Bardwan*, 1863, "c" is interpreted as being a sky generally nearly clouded over and also as a sky covered with clouds. The combination of "b" and "c" is obviously blue sky with some clouds.

In 1826 the meaning of "o" was "overcast, the whole sky covered with thick clouds," but in 1833 this was modified to "the whole sky covered with one impervious mass"—a sky covered with clouds of some formation would be logged as "c" or even "oc" in cases where there were clouds of some formation below the impervious mass.

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The interpretation derived from the study of his logs given in the foregoing remarks is, I think, the traditional version in the Navy.

The present day use of the Beaufort letters has departed from that of Admiral Beaufort in one very important particular, in that it ascribes to the letters a quantitative significance which was never adopted by the originator of the notation. For example, "bc" is used to mean 4/10-6/10th of the sky covered with cloud. It is, however, interesting to note that as from 1st January, 1926, the Meteorological Office is adopting changes in its weather scale which will bring it into very close conformity with the Beaufort Weather Notation of 1838_4 which is the final scale drawn up by Admiral Beaufort himself.

In conclusion I have to express my thanks to Mr. A. F. Beaufort, a Fellow of this Society and a grandson of Admiral Sir Francis Beaufort, for placing at my disposal the private logs to which reference has been made above. Without the use of these logs it would have been impossible to trace the history of the Beaufort Scales for Wind and Weather.

I am also indebted to the Hydrographer of the Navy, Captain H. P. Douglas, C.M.G., R.N., for access to the official logs of H.M.S. *Woolwich*, and to the Deputy Librarian, Mr. J. F. Phillips, at the Admiralty, for photographic copies of the Admiralty *Memorandum* shown in Fig. 2. Access to the other logs was obtained in the usual way through the Record Office.

DISCUSSION.

Captain Sir DAVID BARKER said the Society should thank Captain Garbett for his paper, which showed that much trouble had been taken in obtaining particulars of so remarkable a man as Admiral Beaufort. It was noteworthy that after such a lapse of time much of his scale should be still in use. Beaufort had taken his observations from day to day, had worked them out and finally reduced them to a system which seamen could thoroughly grasp and so give uniformity in the recording of observations. Captain Garbett had done well in giving the Society an account of the manner in which this was accomplished.

Comm. E. C. SHANKLAND said there were one or two points which this informative paper presented, and one was that in the first place he did not think that Beaufort intended to correlate the speed of the ship with the speed of the wind. He started off with a clear method in view of indexing the force of the wind alone so that it could be used on ships at anchor or on ships on a weather shore with strong wind or ships in smooth water. There was, he thought, to-day among meteorologists a feeling that seamen rather embraced too many quantities in their expressions, but there was no doubt but Beaufort in this case started with the idea of giving a precise factor which seamen could use. The point to which he referred was introduced in the previous paper—whether one obtains the maximum by correlating the speed of the ship and the speed of the wind. The other point which he thought the paper made so interesting was that we had, at this distance of time, gone back to the figures which the great man laid down and that was probably the best test of their usefulness.

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Colonel E. GOLD said that he would like to congratulate Commander Garbett on the paper and to thank him for all the trouble he had taken in digging out these historic facts which were of very real interest to meteorologists. The account which they had heard reminded him of a passage in Mahan's "Life of Nelson," in which Mahan laid stress on the importance of "the time and the man" coming together—the opportunity was there and the man was there to take it. He thought that that applied equally to Beaufort and his work for meteorology. He would like to say some things about both the wind scale and the weather scale. The former, from the method of specification, was evidently not a simple scale for the speed of the wind. The appropriate number was obtained by observing the *effects* of the wind, and these effects depended not only on the speed of the wind, but also on the density of the air and on the variations of speed, and possibly also on the state of the sea and the build of the ship. The effect of the density of the air was by no means insignificant. At a height of 10,000 feet the speed of the wind would have to be 20 or 30 per cent. greater than at sea level to produce the same effects on fixed objects. Similarly at the equator the speed would have to be 10 or 20 per cent. greater to produce the same effects as at the pole. Again, the Beaufort number depended not upon the speed of the wind at a given height, but on the speed at all heights up to the top of the sails. The number was therefore a complex function even in respect of the speed of the wind.

At the same time it is certain that what was in the mind of most people who used the Beaufort scale was the desire to get an approximate expression for the speed of the wind. An indication that this is the case is found in the opinion expressed by sailors that a North-West wind of given force produces more sea disturbance than other winds of the same force (in the Northern hemisphere). This suggests that the seaman considers that he has obtained the speed of the wind by his rules and that he can then go back and consider the effect of the wind whose speed he has determined. The example is of some importance because when the sailing ship was replaced by the steamship a practical link for connecting the old observations with the new was provided by the effect of the wind on the surface of the sea. Indeed, the principal criterion used by observers on steamships for estimating the force of the wind nowadays is the effect of the wind on the surface of the sea; and this led him to observe that there was here a cause for discontinuity in the observations because the wind acting on the surface of the sea was the wind at the surface and not the complex function of the wind from sea level to the top of the sails.

There is another important difference between the wind on land and at sea. On land, at any rate on a bare open space, the form of the surface of the land is quite independent of the strength of the wind. We can therefore speak with accuracy of the speed of the wind at 10 metres above the ground, and the height 10 metres is invariable, once it has been fixed. At sea, on the other hand, the form of the surface is dependent on the strength of the wind, and a point in space which is 10 metres above the surface of the sea when it is calm, is no longer at 10 metres above the surface of the sea when there is a gale blowing. At one instant it may not be 10 feet from the surface of the sea; a little later it may be nearly 20 metres. While, therefore, it is practicable to have a Beaufort scale for land in which the numbers are

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definitely related to the speed of the wind at a given height above the ground, say, 10 metres, and to use the records of anemometers to define the limits within which the different numbers of the scale should be used, such a procedure is not applicable at sea. All that one can say is that at sea the rules for estimating the Beaufort numbers should be definitely formulated; and that the speed corresponding with any Beaufort number at the standard height above ground in the land scale should occur with the same Beaufort number over the sea, at some height between the surface of the sea and, say, 50 metres above the surface. If that were done the scales would be reasonably consistent and the numbers in both scales would give a good idea of the general wind current.

In regard to the weather scale, it was clear from the tables which they had seen that Admiral Beaufort was throughout feeling his way towards a scale which could be put into general use *having regard to the state of meteorological knowledge at the time*. He did not think for a moment that if Admiral Beaufort had lived till now and been endowed with eternal middle age that he would have maintained for all time the scale of weather at which he had arrived when he reached middle age a century ago. He would have altered it in the light of subsequent knowledge and the advance of meteorological education. He would, as was now done, have differentiated between heavy rain, moderate rain and slight rain; and between continuous rain and intermittent rain. He would not have been content to use exactly the same entry in his register for a few flakes of snow as he used for a really heavy fall. Such difficulties as these were being got over in practice to-day by the repetition of letters to denote continuity and by the use of capital and small letters and the suffix "o" (which has long been used with the international symbols) to differentiate between slight and heavy, or strong and weak. But the letters which have proved most inadequate for the meteorological needs of the present day are the letters o, b and c. He remembered how inadequate these letters had been on many an occasion during the war when the Army and Air Force in France were much dependent on a knowledge of future weather or even of the existing weather; and most meteorologists must at some time or other have wished for some symbol in the Beaufort letter scale which would enable them to distinguish between a sky covered with high cloud and a sky covered with low cloud. The simple final definitions of Beaufort did not permit of this. The letter "c," for example, might denote either a sky three-quarters covered with cirro-cumulus or a sky completely covered with low strato-cumulus. In such circumstances meteorological records would be much worse than the plain language description of the ordinary citizen: they ought to be better. Again, owing to the use of the term impervious, a relatively thin cloud canopy which would not qualify as "o" in the daytime when the sun was up, would frequently qualify as "o" at night, so that what was "c" in the daytime would be "o" at night. If he (Colonel Gold) might, he would like to suggest a modification which would enable these difficulties to be surmounted. It seemed to him that the letter "g" (gloomy) was really unnecessary in the scale. "Gloomy" was a psychological and not a physical effect.

In addition to "g," the letters "a" and "n" were not used in the scale (although they had a certain meaning in the international division of the day), and by using these two letters and the letter "g" it would not be a difficult matter to arrange a system of letters for the

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state of the sky which would preserve a reasonable continuity with the past and at the same time meet present requirements. One such method of utilizing the letters would be as follows:

1. Restrict the use of the letter "o" to denote a sky completely covered with uniform cloud of the cirro-stratus and alto-stratus types and of a lower form of alto-stratus which is at present called stratus or nimbus, according as rain was not or was falling from it. (It may be remarked that this form of cloud is usually of considerable vertical thickness, is not difficult to identify, and is of great importance in forecasting because it is the cloud which is responsible for the major part of continuous precipitation.)

2. Use the letter "g" to denote all other occasions when the sky is completely covered, *e.g.*, with strato-cumulus.

3. Use the letter "c" for a sky about three-quarters covered with cloud, corresponding with the French "nuageux."

4. Use the letter "b" to denote a sky completely free from cloud. Along with the letters o, g, c and b, use the letters "a" and "n" to denote high cloud and low cloud respectively, so that "oa" would denote a sky covered with cirro-stratus cloud, "on" a sky covered with stratus cloud, the letter "o" standing alone denoting a sky covered with alto-stratus cloud. The letters "ba" and "bn" would then denote a sky in which there was a small amount of intermediate or high cloud or of low cloud respectively, the letter "b" standing alone denoting a cloudless sky. We should then get a table like the following:

High Cloud.	Medium Cloud.	Low Cloud.	
oa	o	on	= completely overcast with uniform cloud.
ga	g	gn	= completely overcast with non-uniform cloud.
ca	c	cn	= sky three-quarters covered.
ba	b	bn	= a little high cloud, cloudless, a little low cloud.

The letter "c" could be used in combination with the letter "g" if desired, to denote a sky nearly, but not quite, completely covered, and the letter "b" could be used in combination with the letter "c" to denote a sky about half-covered. Thus "gc" would be a sky nearly completely covered with cloud of non-uniform type. The combination "oc" would be reserved for sky apparently completely covered with uniform cloud and a considerable amount (about three-quarters) of non-uniform cloud beneath the uniform layer.

The Beaufort letters are of the greatest advantage for describing the sequence of weather and it might be objected that there would be no means of distinguishing between the meaning of the letters "gc" to denote instantaneous description and the use of the same letters to denote a sequence, but as a matter of fact a sequence from "g" to "c" would always have to go through the type "gc" and would be correctly described as "ggcc"; so that there would be no real risk of confusion, although there would be a certain increase in the number of letters used.

One advantage of such a system was that it could be introduced gradually without breaking with the past; because those observers who were not sufficiently interested to adopt the full system of differentiation would be able to continue with their old system until the advantages of the fuller description had been sufficiently demonstrated in practice to make it possible to secure its general adoption.

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He did not think that the system which he had put forward was the only method by which improvement could be effected; he thought the matter was one where improvement was necessary and where discussion was a necessary preliminary to improvement. It was no longer a matter of interest only to this country; the system of Beaufort letters was in use throughout the English-speaking world, including the British Colonies and the United States of America. It was used for observations both on land and at sea. Whatever solution was ultimately adopted must commend itself both to those who made and to those who discussed meteorological observations in all these countries; but the idea that the complexities of the sky could be described by three letters adequately enough for meteorology in its scientific aspect or in its practical applications ought to be abandoned.

Correlation Coefficients.

In connection with the paper by Sir Gilbert Walker and Mr. Bliss, "On Correlation Coefficients, their Calculation and Use," attention may be drawn to a rather interesting result which follows at once from the existence of a negative correlation coefficient of -0.5 between successive differences in a random series of numbers. The authors have shown in Section III. of their paper that with a correlation coefficient of this value the sign of the departure can be forecast correctly on two out of three occasions. It follows, therefore, in a random series, a plus difference will be followed by a minus and a minus by a plus on two occasions out of three. This conclusion can be readily checked by running down such a set of random numbers as is afforded, for example, by the London Telephone Directory.

Some years ago I reached the above conclusion while examining the successive monthly totals of rainfall for London. Forecasting on the basis that if the rainfall in a given month were higher than in the previous month the rainfall in the following month would show a decrease, 67 per cent. of the predictions were successful, a fairly high percentage for long-range forecasting!

The following alternative explanation of this curious result may, perhaps, appeal to the non-mathematical reader. Consider any sequence, A B C, of three successive numbers in a random series. Then, if we represent the *relative* magnitudes of the quantities by the size of lettering, there are only six possible types of sequence,

$$_{A}BC \qquad _{A}Bc \qquad A_{B}C \qquad ABc \qquad A_{B}c \qquad Ac_{B}$$

so long as no two of the quantities have identical values, the chance of which may be made as small as is desired by increasing the precision of measurement. Now there is no reason why any of these six types should occur more frequently than any of the others. In the long run, therefore, we should expect one-sixth of the total number of sequences to fall in each category. It will be observed that in four of the six types a change of sign occurs in successive differences, consequently a forecast indicating a change of sign would be correct twice out of three times.

By reasoning on generally similar lines, it may be shown that if n successive differences have similar signs, the chances are $n+1$ to one in favour of a change of sign in the next difference.

E. G. Bilham.

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ON THE DETERMINATION OF MINUTE PERIODIC VARIATIONS.

By J. BARTELS, Erdmagnetisches Observatorium, Potsdam.

(Communicated by Prof. S. CHAPMAN, F.R.S.)

[Received December 5, 1925.—Read February 17, 1926.]

§1. Useful methods have been invented for determining the lengths of hidden periodicities, but little help will be found in computing the period itself after its length has been stated. The present note has been written to show, in the example of the lunar atmospheric tide at an extratropical station (Potsdam), that the ordinary procedure of taking means can be improved in some cases. The device has been successfully applied to solar diurnal variations of pressure at Antarctic stations, where the scarcity of the material required a delicate treatment.[1] Afterwards it was found out that the scheme may be regarded as a development of the periodogram analysis introduced by Whittaker.[2]

§2. It is based on the following simple remark drawn from ordinary statistics[3]: Given a number of observations of unequal precision for an unknown quantity, it may be possible to ascribe to each observation the approximate numerical value of its error, so that groups g according to this error may be formed, each group comprising all observations (number n_g) with an error between convenient limits. The mean error in each group may be A_g. The mean result of the whole series may be computed in two ways: by taking the mean of all observations without distinction, or by giving to each observation a weight $p_g = 1/A_g^2$ according to its group.

Generally, if $x, y, z, \ldots$ are observations of the same quantity, with the respective mean errors $m_x, m_y, m_z, \ldots$, the square of the mean error of the linear function $(ax + by + cz + \ldots)$ is equal to $(a^2m_x^2 + b^2m_y^2 + c^2m_z^2 + \ldots)$; and, in particular, this expression becomes nm^2 for the simple sum of n observations $x, y, z, \ldots$ each having the same mean error m. Applying this, we get for the square of the mean error of the single group sum $n_gA_g^2$, and again, for that of the final sum of all groups taken together:—

(1) In the first case (without weighting)

$$M_1^2 = \sum_g n_g A_g^2,$$

(2) In the second case

$$M_2^2 = \sum_g p_g^2 n_g A_g^2 = \sum_g (n_g / A_g^2).$$

Now the mean result is formed by dividing the sum by a denomina-

[1] *Cf. Bericht über die Tätigkeit des Preussischen Meteor. Inst., Berlin*, 1920-23, pp. 101-110; *Annalen der Hydrographie, Hamburg*, 1923, pp. 153-160.

[2] *The Calculus of Observations*, London, 1924, Chapter XIII.

[3] *Cf.* D. Brunt, *The Combination of Observations*, Cambridge, 1923, Chapter IV.

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tor which represents the sum of the weights, that is $\Sigma_g n_g$ in the first case, and $\Sigma_g p_g n_g = \Sigma_g (n_g/A_g^2)$ in the second case. Of course we have to divide M_1^2 and M_2^2 by the squares of these denominators, in order to obtain the following expressions for the squares of the mean errors of the results:

In the first case

$$m_1^2 = \Sigma_g n_g A_g^2 / (\Sigma_g n_g)^2,$$

In the second case

$$m_2^2 = 1 / \Sigma_g (n_g/A_g^2).$$

The relation $m_2^2 \leqq m_1^2$ follows easily from $(\Sigma uv)^2 \leqq \Sigma u^2 \Sigma v^2$. Indeed, m_2 is the smallest possible value for the mean error of any weighted mean of the observations. The weighted mean is therefore more reliable than the simple mean.

§3. This may be applied to the determination of lunar variation of pressure at Potsdam.[4] The "observations" are the 24 hourly values of pressure of a single solar day; the "error" may be roughly estimated from the absolute range, which is sufficiently nearly proportional to the mean deviation of the single hourly values from the daily mean. Group 0 comprises all days with a range of from 0.0 to 0.9 mm. of mercury, and group 1 all days with a range of from 1.0 to 1.9 mm. and so on, group 11 all days with a range above 11.0 mm. The mean range A_g has been directly computed for groups 0 and 11, while for the other groups it was found sufficient to take $A_1 = 1.5$ mm., $A_2 = 2.5$ mm., etc.

The different columns mean:—

Winter = November to February, Summer = May to August.
g = group.
n_g = number of days in group.
A_g = mean range of days in group.
N_g = sum of n_g up to g = number of days used in forming m_1 and m_2.
m_1 = mean non-lunar range, to be expected in taking the simple unweighted mean of all days up to group g.
m_2 = mean non-lunar range, to be expected in the *weighted* mean of all days up to group g.

The table clearly shows how the simple mean is spoiled by including days with higher ranges, while the *weighted* mean is improved, the higher ranges being throttled.

§4. It would be possible to obtain still smaller ranges in the mean by sub-dividing the groups, but not much would be gained. On the contrary, it would be dangerous to do so, because the influence of the few days with the lowest range would become too strong, which would render the elimination of the solar variation more difficult. For it will be shown elsewhere that this solar variation has a very distinct "anticyclonic" type on quiet days, differing little, but systematically from the mean of all days (*cf.* the papers cited in §1).

§5. The actual computation for Potsdam and Hamburg, now

[4] *Cf.* also S. Chapman, *Monthly Notices R. Astron. Soc.*, Vol. **78**, 1918, pp. 635-38, and his papers on Lunar Variation in recent volumes of this Journal.

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in progress, uses only the groups 0 and 1 without weighting, that is only a little less of the material available than in the example given by S. Chapman for Greenwich. As shown in the table, very little would have been gained by taking any days with higher ranges, though the labour involved would increase faster than the number of days, owing to their disturbed character. This holds especially for summer, while for winter groups 2 and 3 will be computed separately and afterwards combined with groups 0 and 1 (weighted), reducing the mean error from 0.064 to 0.052 mm.

TABLE I.—Absolute Daily Range of Pressure at Potsdam, 1893-1922, and Its Effect on the Computation of Lunar Variation.

g	Winter.					Summer.				
	n_g	A_g mm.	N_g	m_1	m_2	n_g	A_g mm.	N_g	m_1	m_2
				0.001 mm.					0.001 mm.	
0	61	0.71	61	92	92	91	0.73	91	77	77
1	437	1.5	498	64	57	885	1.5	976	46	42
2	403	2.5	991	65	50	959	2.5	1035	46	37
3	534	3.5	1525	68	48	687	3.5	2622	49	36
4	414	4.5	1939	71	47	404	4.5	3026	52	35
5	349	5.5	2288	75	46	284	5.5	3310	55	35
6	299	6.5	2587	79	46	178	6.5	3488	58	35
7	230	7.5	2817	83	46	89	7.5	3577	60	35
8	207	8.5	3024	88	45	51	8.5	3628	61	35
9	158	9.5	3182	91	45	33	9.5	3661	63	35
10	89	10.5	3271	94	45	20	10.5	3681	63	35
11	335	13.9	3606	110	45	9	13.2	3690	64	35

§6. Attention may be drawn to the necessity that the grouping of the observations must be made according to a characteristic which is wholly independent of the quantity searched for. Otherwise systematic errors would be introduced in weighting. Thus, it would be wrong (to a certain degree) to calculate the solar variation in the same way, the "quiet days" representing special anticyclonic conditions as mentioned above. The same holds for magnetic variations. But in the case of lunar variation of pressure no serious objection exists against classifying according to the absolute range, since the lunar variation is so small that it does not appreciably affect the range.

S. Chapman has pointed out a marked annual variation in the lunar atmospheric tide. Therefore it would be objectionable to form the annual mean of the lunar tide directly from the single days, summer being represented by nearly double the number of quiet days as winter. Weighting the seasons according to their mean error would be still more in favour of summer conditions. An annual value, which is comparable with that of tropical stations, can be obtained only by combining the means of summer, equinox and winter with equal weight, though the mean error of the result is necessarily greater from the statistical point of view.

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DISCUSSION.

Prof. S. CHAPMAN remarked that the paper was very useful in drawing attention to certain important points in the calculation of the lunar atmospheric tide. It showed how small is the gain in the accuracy of the determination of the tide, got by taking into account days other than those of small range. It is clearly best to throw away two-thirds of the data at a station like Greenwich or Potsdam, where the irregular variations of barometric pressure are considerable: because even if the results from the remaining days are suitably weighted, their value is too small in proportion to the labour involved in getting them: while if the results from the days of larger range are not weighted, their inclusion may greatly increase the accidental error in the final determination.

The PRESIDENT (Sir Gilbert Walker, F.R.S.) pointed out the importance of harmonic analysis in the examination of questions in cosmical physics, and thought that in such applications the paper would be of decided value.

Mauritius, Upper Air Investigation.

We are indebted to Mr. A. Walter for permission to publish an account of Upper Air Investigation at Mauritius, from the full report of which the following brief summary is made. Cloud observations, which were first begun in 1904 with a Marvin nephoscope, were interrupted in 1911 and not recommenced until 1923, when a new Fineman nephoscope was installed, since when regular observations have been obtained. A kite station has also been equipped, but up to the present the greatest height attained has not exceeded 4,000 feet.

The pilot balloon ascents have all been made at the Aerological Station at Vacous, which is situated at a height of 425 m. above sea level. The ground is flat all round for a distance of 8 km. except for a narrow belt between S and SE, where at a distance of 4 km. the level rises a further 175 m. The tail method is alone employed, the tails being either 10 m. or 40 m. in length, although the latter is reduced to 30 m. with high winds. The observations are reduced by graphical methods on millimetre ruled paper.

The results so far obtained from 137 ascents made between July 7 and November 30, 24 of which reached a height of 6,000 metres, show:—

1. That there is a steady increase in velocity of the SE trade up to a height of 500 metres with a slight backing (probably only local) towards the north.
2. That the velocity falls off rapidly above 750 m. until there is an almost dead calm between 1,000 m. and 2,000 m.
3. That above this level there exists either a North-Westerly or a South-Westerly wind which becomes almost due Westerly at a height between 6,000 and 7,000 m. This height is, however, variable. With the passage of a trough of low pressure Westerly winds may be encountered below 1,000 m., while on a few occasions they do not occur below 6,000 m. The average height appears to be between 3,000 and 4,000 m.

Abstract.

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REPORT OF THE COUNCIL

FOR THE YEAR 1925.

[Submitted to the Annual General Meeting, January 20, 1926.]

The year 1925 marked the Seventy-fifth Anniversary of the foundation of the Society and was therefore one of exceptional interest. Apart from this, considerable activity was shown in various other directions, notably in the improvement of the *Quarterly Journal*, the provision of a Fellows' reading-room, and the repayment of a portion of the debentures which had been issued to certain Fellows in connection with the purchase of the freehold of the Society's house.

ADDRESS TO THE KING.—The Council and Fellows presented a loyal and dutiful address of sympathy and condolence with His Majesty the King on the occasion of the death of His Royal Mother, Queen Alexandra.

SEVENTY-FIFTH ANNIVERSARY MEETINGS.—The Society was founded on April 3rd, 1850, and the 75th anniversary meetings were held on April 21st and 22nd, 1925.

A telegram of loyal greeting was sent to H.M. the King, Patron of the Society, and the following reply which was received from His Majesty was read at the meeting on the 22nd April:—

H.M. Yacht Victoria and Albert.

On the occasion of the 75th anniversary of the foundation of the Royal Meteorological Society, I am commanded to express the sincere thanks of the King to the Fellows of the Society for their message of homage and loyalty, which His Majesty has received with much satisfaction.

As Patron of the Royal Meteorological Society the King rejoices in the thought that recent years have seen important advances in the science; and he earnestly trusts that the Society will be able to record still further developments in their valuable and interesting labours.

STAMFORDHAM.

The celebrations included a visit to Kew Observatory in the afternoon of April 21st on the invitation of Dr. G. C. Simpson, F.R.S., Director of the Meteorological Office, and Dr. C. Chree, F.R.S., Superintendent of the Observatory; a conversazione in the rooms of the Society on the evening of that day; and an anniversary meeting in the afternoon of the 22nd at which Prof. E. van Everdingen, Honorary Member, President of the International Meteorological Committee, delivered a lecture on "Clouds and Forecasting Weather." The Fellows and their guests dined at the Hotel Rembrandt on the 22nd. A large number of distinguished persons were invited to the meetings. The members of the International Commission for the exploration of the Upper Air, which had just concluded its meetings in London, were present and the opportunity was taken of introducing to the Fellows those recently elected Honorary Members who had found it possible to attend the celebration.

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A full account of the meetings is printed in the *Quarterly Journal* for July, 1925.

THE QUARTERLY JOURNAL.—A Committee was appointed by the Council in 1924 to consider what steps should be taken in order to widen the appeal of the Journal among the Fellows of the Society.

The Committee reported in 1925, and as a result, Mr. R. G. K. Lempfert, Foreign Secretary, was appointed Honorary Editor, and member of the Editing Committee.

By the generosity of three members of the Council, a sum of £150 per annum has been placed at the disposal of the Council for five years for the purpose of improving the Journal in the sense mentioned. This has enabled the Council to provide additional assistance in the preparation of the Journal.

The Journal for 1925 is the largest ever issued and contains 442 pages, exclusive of the *Bibliography of Meteorological Literature* which is now published separately. A notable feature of the 1925 Journal is the improvement and increase in the notes of general meteorological interest.

MEMOIRS.—While the Council are fully aware of the necessity of widening the appeal of the Journal, they are of opinion that the publication of papers of a highly technical nature should not be neglected. They accordingly made application to the Royal Society for a sum of £150 from the Government Publication Grant, and are glad to report that the Royal Society have acceded to the application. Arrangements are now being made for the publication of the more technical papers in a series separate from the Quarterly Journal, to be known as *Memoirs of the Royal Meteorological Society*.

FELLOWS' READING-ROOM.—In the Council's Report for 1922, reference was made to a proposal for fitting up one of the rooms of the Society as a room in which Fellows who desire to consult the library or to meet their friends can do so in comfort. The Council are glad to be able to report that with the assistance of a few Fellows, this proposal has now been carried out and that the front room on the ground floor, formerly used as an office, has been furnished and is now open for the use of Fellows. Arrangements have been made by which Fellows can obtain afternoon tea between the hours of 3 and 5 p.m.

Portraits of all past Presidents from 1850 are being obtained and it is proposed to hang the portraits in the meeting room.

FINANCE.—Reference is made elsewhere in this Report to support of a special kind which the Society has received in the year under review, but the finances of the Society (always a matter of some anxiety to the Council) have in this year had to receive special consideration. The Fellows are aware that in order to provide the money necessary for the purchase and equipment of the Society's house, the Council arranged for the issue of £6,300 Debentures bearing interest at the rate of 6 per cent. It was one of the conditions of the issue that not less than £250 annually of these Debentures should be redeemed, beginning in 1926. The Council accordingly were faced with the necessity of providing in 1926 (in addition to the ordinary expenditure and the interest at 6 per cent. on the Debentures) not less than £250 for redemption money—a

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matter of some difficulty. It was therefore with very considerable relief that they were informed that the chief Debenture holders had agreed (the Society repaying £3,000 of the Debentures) to propose to vary the terms of the remaining Debentures by reducing the minimum amount of capital to be repaid annually to £100, and the rate of interest (as from 1st April, 1926) to 5 per cent. They also made the suggestion that in addition to the minimum amount of £100 Debentures, all life compositions received should be earmarked for redemption of Debentures. The Council had no hesitation in accepting this proposal and the suggestion, and they consider that the hearty thanks of the whole Society are due to the Debenture holders for their generous attitude in this matter.

The Council accordingly took steps to provide by the sale of some of the Society's investments £3,000 wherewith to redeem Debentures and this has been done.

As a result the extra strain on the Society's resources is relieved, but the fact remains that the Council must provide in 1926 and thereafter not less than £100 per annum for the redemption of Debentures.

The Council point out that they cannot always look for special contributions or arrangements for the benefit of the Society and its work, and they strongly feel that the Fellows should show their appreciation of the special efforts which have been made in the last year, by increasing the number of Fellows. The contribution of Fellows must always be the main support of the Society and the more Fellows the Society has in its muster, the greater will be the scope of its usefulness to the Science.

The accounts for the year are printed below.

Attention is directed to the item in last year's Statement of Assets "Expenditure on New Premises to date £7,663 15s. 0d." which has been reconsidered and in this year's statement is replaced by "Estimated value of Society's house £5,375." The item "Furniture and fittings, etc.," has at the same time been increased by £100.

OTHER PUBLICATIONS.—*The Bibliography of Meteorological Literature* has been continued, two numbers having been issued during the year.

The *Phenological Report* for 1924, the 34th of the New Series, was presented to the meeting in June. The Council desire to place on record their appreciation of the work of the Phenological Committee, viz., Mr. J. E. Clark, Mr. I. D. Margary and Mr. R. Marshall.

Rainfall Atlas of the British Isles.—The Committee appointed to consider the administration of the British Rainfall Organization Fund, referred to in last year's report, recommended that a Rainfall Atlas of the British Isles should be prepared and published. The recommendation is now being carried into effect. The Atlas will contain 13 quarto maps showing the average distribution of rainfall over the British Isles for each month of the year and for the whole year, two quarto maps showing the distribution of rainfall in the wettest and driest years, and 56 octavo maps showing the distribution of rainfall, expressed as a percentage of the average annual fall, for each individual year from 1868 to 1923.

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Dr. H. R. Mill has kindly undertaken to write the introduction to the Atlas.

REPRINTS OF METEOROLOGICAL PAPERS FROM THE *Proceedings of the Royal Society*.—During the year seven papers have been issued to those Fellows who are participating in the scheme of distribution. Fellows are reminded that the original deposit fee for these papers was exhausted during the year and a further sum of 10s. 0d. is now due from those who started in 1921 and have not already forwarded a second subscription.

FELLOWS.—Particulars as to the number of Fellows are given in the following table:—

	FELLOWS.			HONORARY MEMBERS.
	ANNUAL.	LIFE.	TOTAL.	
December 31, 1924	**628**	**179**	**807**	**11**
Since elected	37	3	40	8
Reinstated	1	1	2	—
Deceased	18	6	24	2
Resigned, etc.	56	—	56	—
December 31, 1925	**592**	**177**	**769**	**17**

There is thus a decrease of 38 Fellows in the course of the year. This, however, includes 11 names which should normally have been removed from the list last year.

The Council record with much regret the deaths of the following Fellows, the dates in parentheses representing the years of election:—

R. B. Booth (1893).
Dr. J. J. Graham Brown (1906).
J. Y. Buchanan, F.R.S. (1901).
Capt. A. Carpenter, D.S.O. (1879).
W. S. Clark (1905).
Alfred Clay (1907).
Dr. T. A. Compton (1867).
Rev. A. L. Cortie, S.J. (1924).
R. J. Cuninghame (1896).
W. P. Gibbons (1905).
W. W. Hamley (1879).
A. H. Laidlay (1918).
E. G. Lamb (1913).
W. E. Markham (1903).
T. H. Morgan (1866).
Sir William Peck (1901).
G. Redpath (1884).
Sir D. L. Salomons, Bart. (1875).
Sir William Schlich (1886).
G. L. Smith (1919).
Miss Frances Sparks (1907).
Mrs. Mary Wilkin (1907).
A. J. Wilmshurst (1900).
C. E. Young (1916).

Of these, special mention may be made of the following:—Mr. J. Y. Buchanan, F.R.S., Councillor during 1903-4; Capt. A. Carpenter, D.S.O., R.N., Councillor from 1897-1903. The list of deaths during the year has never been exceeded. It includes two Fellows elected more than fifty years ago.

HONORARY MEMBERS.—Under By-Law 20 the Society has the power to elect a number of Honorary Members from among persons eminent in Meteorological Science, who are not permanently resident in the United Kingdom. The total number of Honorary

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Members is not to exceed 20 at any one time. No election had taken place since before the war and at the end of 1924 the number of Honorary Members had fallen to eleven. The Council decided that it would be appropriate in the Seventy-fifth Anniversary year to fill the greater number of the vacancies, and the following were accordingly elected Honorary Members during the early months of the year:—

Dr. C. G. Abbot.
Dr. W. van Bemmelen.
Dr. E. van Everdingen.
Dr. F. M. Exner.
Dr. Th. Hesselberg.
Dr. J. Maurer.
Dr. T. Okada.
Dr. A. Wallén.

(See Journal, pp. 157 and 160.)

After the election there was thus one vacancy remaining, but the number has now been increased to three owing to the deaths of Prof. Hildebrandsson, of Sweden, at the advanced age of 87, and of Dr. Ekholm, also of Sweden. Prof. Hildebrandsson was the senior Honorary Member, having been elected in 1880. He was awarded the Symons Medal in 1920.

AWARDS.—The *Symons Medal* is awarded biennially irrespective of sex or nationality, for distinguished work done in connection with meteorological science. By custom successive awards are made alternately to British and foreign meteorologists. This year the recipient should be a British meteorologist and the Council have decided to award the medal to Lieut.-Colonel Ernest Gold, D.S.O., F.R.S.

The *Howard Prize*, consisting of an aneroid barometer, suitably inscribed, was awarded to Cadet H. W. Barnett, of the South African Training Ship "General Botha," for an essay entitled "Icebergs, their distribution and drift." Ten essays in all were received.

DONATIONS TO THE SOCIETY.—The Society has been peculiarly fortunate this year in respect of the number of donations received or promised. In addition to the Grant from the Royal Society, and the contributions from certain Fellows for the improvement of the Journal, already referred to, the following donations should be mentioned:—

A signed portrait of H.M. the King, Patron of the Society, from Comm. L. G. Garbett, Honorary Secretary.

Framed photographs of clouds, from the President, being part of the Royal Society's exhibit from the British Empire Exhibition.

Contributions towards the furnishing of the Fellows' room from Mr. H. Mellish, Past President, and Mr. J. S. Dines.

A number of lantern slides of clouds from Sir David Wilson-Barker, Past President.

A mercurial barometer made by Admiral Sir Francis Beaufort from Mr. A. F. Beaufort.

A considerable number of books and pamphlets, for the Library, as set out in Appendix II.

LECTURE.—On the invitation of the President, Dr. C. G. Abbot, Honorary Member, Director of the Astrophysical Observatory, Washington, very kindly delivered a popular lecture on "Measuring the Sun's Rays" at a meeting on November 11th, 1925.

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APPENDIX

STATEMENT OF RECEIPTS AND PAYMENTS

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance from 1924—Cash at Bank of England	142	7	1			
Deposit at Westminster Bank	100	0	0			
				242	7	1
Subscriptions for 1925	1373	4	0			
,, ,, former years	82	14	0			
,, ,, 1926 and later years	46	0	0			
				1501	18	0
Entrance Fees				44	2	0
Life Compositions				105	0	0
Dividends and Interest				158	5	7
Sale of Publications, Advertisements, etc.				239	4	9
Rent of Maisonette (including Income Tax recovered)				225	0	0
Contribution for administrative purposes from British Rainfall Organization Fund				10	0	0
Contributions to *Journal* Fund				150	0	0
Contributions towards furnishing Fellows' Room				8	0	0
Sale of Investments				3000	0	0
Refund of amount paid in 1924 for repair of anemometer ...				1	7	6
				£5685	4	11

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I.

FOR THE YEAR ENDING DECEMBER 31, 1925.

PAYMENTS.

	£ s. d.	£ s. d.
Debentures.—		
Redemption of 60 Debentures	3000 0 0	
Interest paid on Debentures	348 19 10	
		3348 19 10
Journal, etc.—		
Quarterly Journal, Nos. 212-215	363 17 3	
Illustrations	52 19 8	
Reprints of Papers	54 15 6	
Reviews	5 5 0	
Assistance in preparation of *Journal*	40 0 0	
Bibliography of Meteorological Literature, Nos. 7 and 8 ...	53 6 0	
Monthly Weather Reports, 1924	20 18 8	
Reprints from *Journal of the Physical Society*	25 13 4	
		616 15 5
Printing, etc.—		
General Printing	68 0 9	
Stationery	53 3 4	
Books and Bookbinding	28 0 2	
		149 4 3
Office Expenses, etc.—		
Salaries and Insurance	601 19 7	
Caretaker and Insurance	66 1 8	
Preparation of Bibliography	25 0 0	
Postage	103 11 8	
Telephone Charges	8 19 5	
Auditing Accounts for 1924	10 10 0	
Petty Expenses	22 14 8	
		838 17 0
Coals, Lighting, etc.—		
Coal and Coke	25 3 5	
Lighting	9 0 4	
Water Rate (including £6 14s. 4d. recovered for 1924)	0 5 8	
Insurance	11 7 6	
Furniture and Repairs	16 2 1	
		61 19 0
Miscellaneous Expenditure.—		
Buchan Prize	17 0 0	
Howard Prize	2 2 0	
Furnishing Fellows' Room	60 18 8	
Office Furniture	24 2 6	
Solicitors' Charges *re* House and Debentures, 1921-22	15 18 10	
		120 2 0
Meetings—		
Meeting Expenses, Refreshments, etc.	7 3 11	
75th Anniversary Meetings	93 11 6	
		100 15 5
Balance—		
Cash at Bank of England	248 12 0	
Cash on Deposit at Westminster Bank	200 0 0	
		448 12 0
		£5685 4 11

Examined, compared with vouchers, and found correct.

BALL, BAKER, ASH & CO.,
Chartered Accountants.

FINSBURY COURT, FINSBURY PAVEMENT,
LONDON, E.C.2.
January 12th, 1926.

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APPENDIX

ASSETS AND LIABILITIES,

LIABILITIES.

	£ s. d.	£ s. d.
Subscriptions paid in advance	46 0 0	
Electric Light and Coke	6 1 6	
Quarterly Journal No. 216	162 7 1	
Monthly Weather Reports, 1925, estimated at	21 0 0	
		235 8 7

6% DEBENTURES.

Authorised.—160 Debentures of £50 each charged on all the property of the Society, both present and future ...	£8000 0 0	
Issued.—As at 31st December, 1922, 126 Debentures	6300 0 0	
Less—60 Debentures redeemed during the year	3000 0 0	
		3300 0 0
Excess of Assets over Liabilities*		3561 9 2
		£7096 17 9

* This excess is exclusive of the value of the Library and Stock of Publications.

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I.—continued.

DECEMBER 31, 1925.

ASSETS.

	£ s. d.	£ s. d.
New South Wales 4 per cent. Inscribed Stock, 1933, £649 1s. 7d. @ 91	590 13 3	
Funding Stock, 4 per cent., 1960-1990, £200 @ 85½	171 0 0	
		761 13 3
Note.—The above Stocks are valued at prices estimated by the Society's Broker.		
Subscriptions unpaid, amounting to £229 13s., estimated at ...	50 0 0	
Entrance Fees unpaid	5 5 0	
Interest due on Stock, estimated at	14 0 0	
		69 5 0
Furniture Fittings, etc.	393 9 9	
Instruments	48 17 9	
Estimated value of Society's house, 49, Cromwell Road ...	5375 0 0	
		5817 7 6
Cash at Bank of England	248 12 0	
Cash on Deposit at Westminster Bank	200 0 0	
		448 12 0
		£7096 17 9

Examined, and Securities seen.

BALL, BAKER, ASH & CO.,

Chartered Accountants.

January 12th, 1926.

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APPENDIX

BRITISH RAINFALL ORGANIZATION FUND,

RECEIPTS.

	£ s. d.	£ s. d.
Balance from 1924—Cash at Bank of England	31 10 11	
Deposit at Westminster Bank	250 0 0	
		281 10 11
Rent of 62, Camden Square		60 0 0
Dividends on Investments		92 11 8
		£434 2 7

RESEARCH FUND,

RECEIPTS.

	£ s. d.
Balance, January 1, 1925—Cash at Bank of England	27 6 0
Dividends and Interest	10 0 4
	£37 6 4

SYMONS MEMORIAL FUND,

RECEIPTS.

	£ s. d.
Balance from 1924—Cash at Bank of England	10 3 8
Interest received on Investments	26 5 3
	£36 8 11

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I.—continued.

DECEMBER 31, 1925.

PAYMENTS.

	£	s.	d.
Payment to Observers	36	0	0
Ground Rent	6	1	6
Repairs and Decorations during year	35	5	0
Sundries during year	2	16	9
Insurance	1	7	0
Purchase of four thermometers and repair of hyetograph	5	9	2
Administrative Expenses, transferred to Society's General Account	10	0	0
Balance—Cash at Bank of England	87	3	2
Cash on Deposit at Westminster Bank	250	0	0
	£434	2	7

Note.—The Society holds on account of this Fund £2,151 London and North-Eastern Railway 3 per cent. Debenture Stock, £128 5s. New South Wales 3 per cent. Inscribed Stock, £100 5 per cent. War Stock, 1929-47, £100 5 per cent. National War Bonds, 1927, £50 5 per cent. National War Bonds, 1928.

Examined and found correct.

BALL, BAKER, ASH & CO.,
Chartered Accountants.

January 12th, 1926.

DECEMBER 31, 1925.

PAYMENTS.

	£	s.	d.
Balance, December 31, 1925—Cash at Bank of England	37	6	4
	£37	6	4

Note.—The Society holds on account of this Fund £85 9s. 1d. Consols, and £157 15s. 11d. 5 per cent. War Stock, 1929-47.

Examined and found correct.

BALL, BAKER, ASH & CO.,
Chartered Accountants.

January 12th, 1926.

DECEMBER 31, 1925.

PAYMENTS.

	£	s.	d.
Balance—Cash at Bank of England	36	8	11
	£36	8	11

Note.—The Society holds on account of this Fund £700 Cardiff Corporation Redeemable Stock, 3 per cent., and £100 Registered 5 per cent. National War Bonds, 1928.

Examined and found correct.

BALL, BAKER, ASH & CO.,
Chartered Accountants.

January 12th, 1926.

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APPENDIX II.

DONORS TO THE LIBRARY DURING THE YEAR 1925.

1. INSTITUTIONS.

Aberystwyth, Geographical Association.
Apia Observatory, Samoa.
Azores, Servicio Meteorologico.

Bangalore, Mysore Government.
Bangkok (Siam), Meteorological Office.
Barbados, Colonial Secretary's Office.
Barcelona, Servei Meteorologic de Catalunya.
Batavia, Royal Magnetical & Meteorological Observatory.
Beira, Observatorio Meteorologico.
Berkeley, University of California.
Berlin, Deutsche Meteorologische Gesellschaft.
Berlin, Preussische Meteorologische Institut.
Berwickshire, Naturalists' Field Club.
Bourges, Observatoire.
Bremen, Landeswetterwarte.
Brussels, Académie Royale de Belgique.
Brussels, Ministère des Colonies.
Brussels, Société Belge d'Astronomie.
Brighton and Hove Natural History Society.
Brisbane, Royal Geographical Society of Australasia.
British Guiana, Dept. of Science and Agriculture.
Bucharest, Institutal Meteorologic Central al Romaniei.
Budapest, Hungarian Meteorological Society.
Buenos Aires and Cordoba, Oficina Meteorologica Argentina.

Cairo, Physical Service.
Cairo Scientific Society.
Calcutta, Indian Association for Cultivation of Science.
Calcutta, Indian Tea Association.
Calcutta and Simla, Indian Meteorological Department.
Cambridge, Philosophical Society.
Cambridge Solar Physics Observatory.
Cape Town, Royal Society of South Africa.
Carlsruhe, Badische Landeswetterwarte.
Cashel, Irish Rainfall Association.
Chosen (Korea), Meteorological Observatory.
Christ's Hospital, West Horsham, Natural History Society.
Colombo Observatory.
Copenhagen, Dansk Meteorologisk Institut.
Cordoba, Academia Nacional de Sciencias.
Coventry, City Medical Department.
Davos, Meteorologische Station.
Darmstadt, Landesamt für Wetter- und Gewässerkunde.
Darmstadt, Landwertschaftskammer für Hessen.
Dresden, Sächsische Landeswetterwarte.
Dublin, Royal Irish Academy.
Dublin, Royal Society.

Eastbourne, City Medical Department.
Easton, Pa., American Meteorological Society.
Edinburgh, General Register Office.
Edinburgh, Royal Observatory.
Edinburgh, Royal Scottish Geographical Society.
Edinburgh, Royal Society.
Elisabethville, Vice-Gouvernement Général de Katanga.

Falmouth Observatory.
Felstead School Scientific Society.
Florence, Osservatorio Ximeniano.

Geneva Observatoire.
Geneva, Société de Géographie.
Glasgow, Royal Philosophical Society.
Göteborg, Svenska Hydrografisk-Biologiska Kommissionen.
Greenwich, Royal Observatory.
Grenada, Colonial Secretary's Office.
Guernsey, States Meteorological Station.

Hamburg, Deutsche Seewarte.
Hankow, Griffith John College.
Harpenden, Rothamsted Experimental Station.
Havana, Observatorio del Colegio de Belen.
Havana, Secretaria de Agricultura, Commercio y Trabajo.
Helsingfors, Hydrografiska Byran.
Helsingfors, Meteorologische Zentralanstalt des Finnischen Staates.
Hongkong, Royal Observatory.

Jamaica, Government Meteorologist.

Kiev, Service Météorologique de l'Oukraine.
Kôbe, Imperial Marine Observatory.

Leicester Literary and Philosophical Society.
Leningrad, Central Geophysical Observatory.
Leningrad, Hydrological Institut.

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Lisbon, Observatorio Central Meteorologico.
Lisbon, Sociedad de Geographia.
Ljubljana (Laibach), Institute Météorologique et Géodynamique.
London, Admiralty, Hydrographic Department.
London, Air Ministry, Meteorological Office.
London, General Register Office.
London, Geological Society.
London, Institution of Aëronautical Engineers.
London, Institution of Electrical Engineers.
London, Institution of Sanitary Engineers.
London, Institution of Water Engineers.
London, International Society of Medical Hydrology.
London, Ministry of Agriculture.
London, Physical Society.
London, Royal Aëronautical Society.
London, Royal Agricultural Society.
London, Royal Astronomical Society.
London, Royal Botanic Society.
London, Royal Geographical Society.
London, Royal Institution of Great Britain.
London, Royal Sanitary Institute.
London, Royal Society.
London, Royal Society of Arts.
London, Royal Statistical Society.
Los Angeles, University of California, Southern Branch, Dept. of Geography.

Madrid, Instituto Geografico y Estadistico.
Madrid, Real Sociedad Geografica.
Manila, Weather Bureau.
Marlborough College Natural History Society.
Mauritius, Royal Alfred Observatory.
Melbourne, Commonwealth Weather Bureau.
Mexico, Secretaria de Agricultura y Fomento.
Mexico, Servicio Meteorologico Mexicano.
Mexico, Sociedad Cientifica "Antonio Alzate."
Misusawa, International Latitude Observatory.
Montcalieri, Osservatorio del Real Collegio Carlo Alberto.
Munich, Bayerische Landeswetterwarte.

Nairobi, Kenya, Dept. of Agriculture.
Newport, Isle of Wight Natural History Society.
New York, American Geographical Society.
New York, Central Park Observatory.
New York, National Storm Insurance Bureau.
Nicosia, Cyprus, Public Works Department.
Nottingham City Council.

Oorgaum, Kolar Gold Field Observatory.
Oslo, Geophysical Commission.
Oslo, Norsk Meteorologisk Institut.
Ottawa, Dominion Observatory.
Ottawa, Royal Society of Canada.
Oxford, Radcliffe Observatory.

Pahang, F. M. S. Administration.
Panama, Isthmian Canal Commission.
Paris, Bureau des Longitudes.
Paris, Comité Française de Géodesie et de Géophysique.
Paris, Office National Météorologique de France.
Paris, Service Météorologique de la Ville de Paris.
Paris, Service Technique d'Hygiène.
Paris, Société de Géographie.
Paris, Société d'encouragement pour l'Industrie Nationale.
Perth, Western Australia, Government Statistician's Office.
Philadelphia, American Climatological and Clinical Association.
Philadelphia, American Philosophical Society.
Phu-Lien, Observatoire Central.
Port-au-Prince, Observatoire Météorologique du Séminaire College St. Martial.
Port Moresby, Papua, Government Secretary's Office.
Porto Alegre, Instituto Astronomico e Meteorologico.
Portsmouth, Medical Department.
Prague, Institut Central Météorologique de la République Czecho-Slovakia.
Prague, Institut für Kosmische Physik.

Reykjavik, Vedurstofan.
Rhodesia, Southern, Agricultural Dept.
Rio de Janeiro, Directoria de Meteorologia.
Rio de Janeiro Ministerio da Agricultura, Industria e Commercio.
Rome, International Institute of Agriculture.
Rome, Ministero dei Lavori Pubblici.
Rome, Reale Società Geografica Italiana.
Rome, Società Sismologica Italiana.
Rome, R. Ufficio Centrale di Meteorologia e Geofisica.
Rome, R. Ufficio Centrale di Meteorologia e Geodinamica.
Rome, Union Géodésique et Géophysique Internationale.

San Juan, Porto Rico, West Indian and Caribbean Service.

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Santiago de Chile, Observatorio de "El Salto."
St. Lucia, Government Office.
St. Lucia, Castries Botanical Station.
Stockholm, Abisko Naturvetenskapliga Station.
Stockholm, K. Svensk Vetenskaps-akademie.
Stockholm, Küngl, Sjökarteverket Skeppsholmen.
Stockholm, Statens Meteorologisk-Hydrografiska Anstalt.
Stockholm Svenka Hydrografisk-Biologiska Kommission.
Stockholm, Telegrafverkets Provnings-anstalt.
Stonyhurst College Observatory.
Strasbourg, Institut de Physique du Globe.
Subiaco, Observatorio di Montecassino.
Sydney, N.S.W., Royal Society.

Tacubaya, D.F., Mexico, Estudios Geograficos y Climatologicos.
Teddington, National Physical Laboratory.
Tel Aviv, Jaffa, Meteorological Station.
Tokyo, Central Meteorological Observatory.
Tokyo, Imperial University.
Tokyo, National Research Council of Japan.
Toronto, Meteorological Office.
Toronto Observatory.
Tortosa, Observatorio del Ebro.
Tripoli, Sezione Meteorologica.
Tsingtao Observatoire.
Turin, Società Meteorologica Italiana.

Upsala, Observatoire Météorologique de l'Université.
Utrecht, K. Nederlandsch Meteorologisch Instituut.

Venice, Ufficio Idrografico R. Magistrato delle Acque.
Veronesh University.
Vienna, Zentralanstalt für Meteorologie und Geodynamik.

Warsaw, Meteorological Institute.
Washington, Carnegie Institution.
Washington, Hydrographic Office.
Washington, National Academy of Sciences.
Washington, Smithsonian Institution.
Washington, Tropical Plant Research Foundation.
Washington, U.S. Coast and Geodetic Survey.
Washington, U.S. Dept. of Agriculture, Bureau of Agricultural Economics.
Washington, Weather Bureau.
Wellington, N.Z., Census and Statistics Office.
Wellington, N.Z., New Zealand Lands and Surveys.

Yorkshire Philosophical Society.

Zi-Ka-Wei, Observatoire Magnetique, Météorologique et Sismologique.
Zomba, Meteorological Department.
Zürich, Schweizerische Meteorologische Zentral-Anstalt.

2. Individuals, Publishers, etc.

Librarie Félix Alcan.
W. H. Alexander.
Anders Ångström.
R. W. Ascroft.
J. B. Baillière et fils.
A. A. Barnes.
J. Baxendell.
Conrad Beck.
Louis Besson.
G. E. Body.
Gebrüder Borntraeger.
S. Morris Bower.
Rev. A. H. Boys.
C. E. P. Brooks.
C. F. Brooks.
H. J. Browne.
Cambridge University Press.
E. E. Canney.
Dr. Ford A. Carpenter.
Dr. C. Chree.
A. B. Dobrowolsky.
C .K. M. Douglas.
J. Dover.
Prof. F. Eredia.

Prof. E. van Everdingen.
Dr. H. Ficker.
I. V. Figourovski.
Haakon Foss.
Wilson L. Fox.
Federico G. Fuchs.
E. Gherzi.
Ginn & Co.
Gustau Gili.
Dr. I. Gyorffy.
Dr. G. Hellmann.
N. Holden.
D. W. Horner.
H. Hubert.
J. Hunter.
Ellsworth Huntington.
H. E. Hurst.
Dr. E. Ihne.
K. Knoch.
E. Lamb.
Graham C. Lawson.
F. Lindholm.
Marconi's Wireless Telegraph Co.
Dr. E. G. Mariolopoulos.

Miss C. Marshall.
Jean Mascart.
J. Maurer.
H. Mellish.
Methuen & Co.
Th. Moreux.
W. Niebrzydowski.
Madame Perez.
O. Pettersson.
W. H. Pickering.
Ch. Poisson.
L. F. Richardson.
P. Rintoul.
Rochester, N.Y., Taylor Instrument Co.
Sir Napier Shaw.
Ernesto Sifontes.
R. Sutcliffe.
Gilbert Thomson.
Prof. R. DeC. Ward.
The Editors of—
English Mechanics.
Nature.
Observatory.
Wireless Weekly.

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PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 20, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

T. V. RAMACHANDRA AIYAR, B.A., Central Observatory, Bangalore;
PATRICK HENRY HEPBURN, LL.B., F.R.A.S., 68, Parliament Hill, N.W.3;
STEPHEN GEORGE GORDON KELLIHER, Kuala Lumpur, Federated Malay States;
Captain E. W. G. TWENTYMAN, Suva, Fiji;
Prof. ERNEST LUCAS WATKIN, M.A., University College, Southampton; and
GEOFFREY WATTS, 78, Earlham Grove, Forest Gate, E.7.

February 17, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

ARCHIBALD FERGUSON MACKECHNIE, 43, Sheen Road, Richmond, Surrey;
LIONEL PATRICK MARTIN, Grenham House, Birchington-on-Sea;
ERIC NIMMO, Chinley, Grange Road, Broadstone, Dorset; and
HERBERT WILLIAM STRONG, M.B., Surg. Lt., R.N., The Rectory, Arklow, Co. Wicklow.

January 20, 1926.

Annual General Meeting.

Mr. C. J. P. CAVE, M.A., President, in the chair.

Mr. H. E. CARTER and Mr. S. F. WITCOMBE were appointed scrutineers of the ballot for the Council.

The Report of the Council, which was in the hands of the Fellows of the Society present, having been taken as read, its adoption was briefly proposed by the President and seconded by the Secretary. The meeting resolved "That the Report of the Council be received and adopted, and that it be printed in the *Quarterly Journal.*"

Mr. MARK ZAMBRA, in proposing "That the thanks of the Society be given to the Council for their services during the past year," said he was glad to have the opportunity of doing so. He could not recall the names of all the people who had served on the Council in previous years, but there was one name, that of Mr. Mellish, which had occurred for many years, and he wished, in putting the resolution, to couple with it the name of Mr. Mellish in recognition of his services over so long a period.

Mr. L. C. BONACINA said he was pleased to second the proposal. He heartily endorsed all that Mr. Zambra had said, but would like to include also the names of Sir Napier Shaw, who had steered the Society's affairs through the difficult days of the war, and of Mr. J. S. Dines, who served as secretary for a long time, together with that of Mr. Hooker, a past president.

The PRESIDENT then reviewed the activities of the Society during the past year, and concluded by exhibiting numerous and interesting lantern slides of cloud photographs.

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Mr. MELLISH thanked the President heartily for his two years' work and for his interesting address. The Society was indebted to Mr. Cave for taking on the duties of President for a second term of office. It was not often the Society had asked anybody to resume presidential duties, and he was sure the results had been abundantly justified. Mr. Cave had put in two years of very strenuous work, including all the work in connection with the 75th anniversary celebrations. Might not we also couple with his name that of Mrs. Cave, who helped the Society so admirably in acting as hostess on those occasions? He would like to return to her also a hearty vote of thanks. He had now to propose "That the thanks of the Society be given to Mr. C. J. P. Cave for his services as President during the past year and for his Address, and that he be asked that the Address might be printed in the *Quarterly Journal.*"

Captain Sir DAVID WILSON-BARKER said it was a great pleasure to him to second the motion. Mr. Cave was distinguished for his photography of clouds. He (the speaker) had also done some work in that respect and the display to-night gave him an opportunity of seeing the advances which had been made in that art.

The PRESIDENT said he was very much obliged to the Fellows for the kind way in which they had received what Mr. Mellish had proposed and Sir David Wilson-Barker had seconded. He could only say that in his terms of office he had felt thoroughly the help which the Council and officers of the Society had given him. He did not think it was possible to have more congenial Councillors and officers. He thought that in Mr. Corless and Commander Garbett the Society had two Secretaries who were the best possible it could have. Without their help he did not know how he would have got on. He would like also to say the same of Mr. Druce, who had been persuaded to undertake again the office of Honorary Treasurer, a post to which was attached a very great deal of work, not apparent to most of the Fellows of the Society. He was very much indebted to Mr. Druce for consenting again to become Treasurer. He would also like to thank Mr. Lempfert, the Foreign Secretary, who had also undertaken the arduous duties of editing the *Journal*. He was very grateful to him for coming to the support of the Society at a time when the whole future of the *Journal* was very much in the balance, and he was quite sure that his guiding hand would make a great success of the publication.

The SCRUTINEERS then declared the following to be the Council for the ensuing year:—

PRESIDENT.

Sir GILBERT WALKER, C.S.I., F.R.S.

VICE-PRESIDENTS.

CHARLES JOHN PHILIP CAVE, M.A., J.P.
Colonel HENRY GEORGE LYONS, D.Sc., F.R.S.
GEORGE CLARKE SIMPSON, C.B.E., D.Sc., F.R.S.
GILBERT THOMSON, M.A., F.R.S.E.

TREASURER.

FRANCIS DRUCE, M.A., F.L.S.

SECRETARIES.

RICHARD CORLESS, O.B.E., M.A.
Commander L. G. GARBETT, R.N., F.R.G.S.
Major A. J. H. MACLEAN OF ARDGOUR.

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Photograph by Foulsham and Banfield, Ltd.

CHARLES J. P. CAVE, M.A.

(President of the Royal Meteorological Society, 1924-1925.)

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Photograph by J. Russell and Sons.

Lieut.-Col. ERNEST GOLD, D.S.O., F.R.S.

(*Symons Medallist*, 1926.)

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FOREIGN SECRETARY.

R. G. K. LEMPFERT, C.B.E., M.A., F.Inst.P.

COUNCILLORS.

ROWLAND ARNISON, F.R.G.S.
Miss E. ELAINE AUSTIN.
CHARLES ERNEST PELHAM BROOKS, M.Sc., F.R.A.I.
Professor SYDNEY CHAPMAN, D.Sc., F.R.S.
J. EDMUND CLARK, B.A., B.Sc.
MAURICE ALFRED GIBLETT, M.Sc.
HAROLD JEFFREYS, D.Sc., F.R.S.
HAROLD KNOX-SHAW, M.A., F.R.A.S.
IVAN DONALD MARGARY, M.A.
LEWIS FRY RICHARDSON, B.A., F.Inst.P.
Lt.-Commander ERNEST CLAUDE SHANKLAND, R.N.R.
FRANCIS JOHN WELSH WHIPPLE, M.A., F.Inst.P.

Mr. CAVE having vacated the chair and handed over the keys of office, the chair was taken by Sir GILBERT WALKER, who expressed his thanks to the Fellows for the honour they had shown him.

SYMONS MEMORIAL MEDAL, 1926.

The presentation of the Symons Memorial Medal for 1926 was made at the Annual General Meeting of the Society on January 20, the recipient being Colonel ERNEST GOLD, D.S.O.

The PRESIDENT, in presenting the Symons Gold Medal, said Colonel Gold needed no introduction to the Society. His meteorological work had been before the Society for very many years. In the early days of upper air research he turned his attention to the upper air observations from the theoretical side. In 1911 the German Meteorological Society offered a prize for the best essay on the International Kite and Balloon results. The prize was open to people of every nationality and it was Colonel Gold who won the prize. You will find the work of Colonel Gold in the *Journal* of the Society and the *Proceedings* of the Royal Society and in other places, and he would not, therefore, dilate upon them, but he would like to mention that, during the war, Colonel Gold was in charge of the meteorological observations in France and was known all over the areas occupied by the British Army as "Meteor G.H.Q." He did not think everybody realized what a lot they owed to Meteor G.H.Q. At the beginning of the war, meteorology had hardly come into its own as far as war was concerned, and it was largely due to Colonel Gold's initiative and his ability that meteorology became so important, not only in regard to flying but to artillery also. It was to Colonel Gold that the Army owed this service. In particular, Colonel Gold had had to make one forecast which was as trying a forecast as ever any man had to make, and on which depended particular operations. It was successfully made under most difficult meteorological circumstances, and on that occasion Colonel Gold was awarded the D.S.O. He now had to offer to Colonel Gold the highest award that this Society had to offer, the Symons Memorial Medal.

Colonel ERNEST GOLD, D.S.O., F.R.S., thanked the President heartily for the kind words which he had said in presenting him with the Medal. He also thanked the Council of the Society for the honour

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they had done him in conferring the medal upon him. He had read that day in the *Quarterly Journal* of the Society for 1900 a brief account of the life of Mr. Symons and the interesting note which the late Mr. Marriott wrote upon the bequest which Mr. Symons made to the Society's library. He was struck, if he might say so, with Mr. Symons's youth. It was seventy years ago this March since Mr. Symons was elected a member of the British Meteorological Society, at the age of seventeen; and he was specially interested in one part of Mr. Marriott's note where he reproduced a short paper which Mr. Symons published at the age of twenty-one, giving a collection of barometer readings, properly reduced to sea-level, from a selection of stations for this country, collected, he thought, as the result of a letter which Mr. Symons himself had sent to the *Times*, on the occasion of a great depression which crossed the country very slowly at Christmas, 1859. The barometer fell in Cornwall to about 28.4 inches or 960 millibars. Mr. Symons himself had been observing the barometer in London at that time (he believed by observations every quarter of an hour, because he was very interested in the way in which it had fallen and recording aneroid barometers were not then so plentiful as they are now). Mr. Symons was responsible for the adoption of 12 inches as the standard height and 5 and 8 inches as the standard diameters for British raingauges. He was responsible for the adoption of the Stevenson screen as the standard exposure for thermometers, but in neither case was his choice arbitrary. He had first instituted a series of experiments in connection with raingauges and thermometer screens of different types, and his recommendations were based on the results of the experiments. He had quoted these things not as in any way covering the wide field of Mr. Symons's activity, but rather as indicating, in one or two cases which had struck him, how the passage of time had justified the soundness of Mr. Symons's early judgment. The volumes of the Society's *Quarterly Journal* were full of interest, intrinsic interest, and the volumes for 1900-1 were not lacking in that respect. To him they would have an added special interest in future because they contained the account of the life of the man in whose honour this medal was instituted, and, might he add, thinking of a remark which Mr. Bonacina had made, of the Address which Mr. Symons prepared to give at the Society's Jubilee, a Jubilee to which the next oldest Meteorological Society, the German Meteorological Society, sent representatives and congratulated the British Meteorological Society particularly, because at the time this Society was founded, meteorology was in danger of being swamped by a combination of astronomy, astrology and physics. It was due to the guidance of those early presidents and members of the Society that meteorology through all those years had advanced to the position of a science. In the supplement to *Nature* of last week there was a quotation from Wordsworth about "those Elysian plains where, throned in gold, Immortal Science reigns," and the main source of happiness and inspiration for the man of science comes to him from those plains themselves. No one who had entered them could be indifferent to their charm, although he must be conscious of his inability to appreciate fully their beauty; and conscious, too, of the arduous struggles required of those who climb from the plains to where the edelweiss blooms, or to the passes where the fairest gentians grow on the very rocks which look so bare and uninviting in the distance. At such times a small piece of the throne may be welcome to the ardent but tried pioneer.

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When he entered the service of meteorology only twenty years ago —what a twenty years!—the gradient wind was a mere mathematical exercise for people who played with an imaginary atmosphere free from the laws of physics; the stratosphere was a physical anomaly, half French, half German, half true; eddy motion was a thing of dust-devils and of the soaring albatross; radiation was best known—in defiance of all the rules for the preparation of manuscript for the printer—as the qualifying adjective of two singularly ineffective thermometers; the squall line was only just being recognized by Mr. Lempfert and M. Durand Greville; the discontinuities of the cyclone and the life history of air currents were practically unknown. Now, all these things were recognized; the reasons for them and their method of working were understood by the young meteorologists of to-day, who were enabled to carry on the further development of our science. So far as he had had any share in the elucidation of some of these mysteries or in the establishment of the truth of any of these generalizations, it had been due to one whom he had hoped to see here to-night—Sir Napier Shaw. He (Sir Napier Shaw) had shared or stimulated all these discoveries by whomsoever they had been brought to fruition. In truth, the medal ought a second time to have been Sir Napier Shaw's rather than his. But since the Council had decided to confer it upon him, he had wondered to himself what its purpose was, and he had thought that its purpose was twofold. To one he had already alluded in passing, it was a piece of the throne; Milton had a translation of a line of Horace which fits it not inaptly, "as some teachers give to boys junkets and knacks to make them learn apace," so was this medal meant to be an encouragement in the pursuit of science when the spirit flags or the attention wanders. But when he thought of the man in whose honour the medal was instituted and the names, honourable and honoured among meteorologists, of those to whom it had been given, names of men no longer with them—Buchan, Hann, Strachey, Teisserenc de Bert, Hildebrandsson, Cleveland Abbé and Angot—the medal had for him another and an abiding significance; and if he might again quote Milton (with one word changed):

> "Nor shall I count it heinous to enjoy
> The public marks of honour and reward
> Conferred upon me for the piety
> Which to my science I was judged to have shown."

CORRESPONDENCE AND NOTES.

A Week of Fog.

Mr. C. K. M. Douglas writes:—

"In a note under the above heading in the January number of the *Journal* (pp. 105-108) the following sentence appears:—'In the eight days the rise in temperature at 10,000ft. amounted to about 33° F., a heating which approximately corresponded to a descent of 6,000ft. or, roughly, 750ft. per day.'

"This is clearly an error, for with a normal lapse rate a descent of 16,000ft. would be required to raise the temperature at 10,000ft. 33° F. Curve 1 (Fig. 1) shows a lapse rate from 10,000 to 20,000ft. slightly above normal. The troposphere was then very cold, and it is therefore

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almost certain that the base of the stratosphere was low, say, 26,000ft. It is just conceivable that the rise of temperature at 10,000ft. was caused by descent from the top of the troposphere, but the even larger rise at 15,000ft. cannot be explained in this manner and must have been partly due to horizontal motion. The warm dry air found in the layer of a few thousand feet above anticyclonic inversions can best be explained by a large descent from the upper half of the troposphere, but in order to explain the rise in temperature at greater heights, both in this and similar cases, one must take into account also horizontal motion."

We are indebted for the correction, but Mr. Douglas's figure of 16,000ft. gives an error almost equally large in the opposite direction. It has apparently escaped his notice that the lateral movement, which he mentions, had already commenced on November 11. A decided change in the lapse rate is to be noted as occurring above 14,000ft. The dry adiabatic through the 10,000ft. level of Curve 4 would therefore cut Curve 1 not at 26,000ft. as he suggests, but some 3,000 to 4,000ft. lower down.

Evaporation at Stoner Hill, Petersfield, and Camden Square, London, during 1925.

Mr. C. J. P. Cave has forwarded the following figures of evaporation registered at Stoner Hill, Petersfield, during 1925. To these are added the monthly totals for Camden Square, London.

At both stations the figures for December are somewhat doubtful owing to frost, which, by freezing the water in the tank during part of the month, prevented the observations from being taken. The readings, however, in both cases have been adjusted after consultation with the Meteorological Office.

Height of gauge above Mean Sea Level:—Stoner Hill, 747 feet; Camden Square, 110 feet.

Month.	Stoner Hill.	Camden Square.	Month.	Stoner Hill.	Camden Square.
	ins.	ins.		ins.	ins.
January . .	0.24	0.12	August . .	2.03	1.58
February . .	0.26	0.30	September . .	1.73	1.01
March . . .	0.96	0.83	October . .	1.16	0.56
April . . .	1.37	1.30	November . .	0.59	0.37
May . . .	2.27	2.34	December . .	0.00	0.00
June . . .	3.93	3.48		——	——
July	3.18	2.61	Total . .	17.72	14.50

The total rainfall during the year was 48.81 ins. at Stoner Hill and 24.91 ins. at Camden Square.

Meteorological Characteristics associated with the South-Westerly Type of Weather at Cranwell, Lincolnshire.

The following note is a short *précis* of a paper written by Messrs. W. H. Pick and G. A. Wright, and is based on an examination of the 07h. charts published in the *Daily Weather Report* of the Meteorological Office, London, for the period January 1920 to October 1925. By the kindness of the authors the complete MS. has been lodged in the

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Society's Library, and is available for reference by those desiring more detailed information than it is possible to give in this condensed summary.

The pressure distribution which produces the South-Westerly type of weather at Cranwell occurs when pressure is high over the Bay of Biscay and the Spanish Peninsula, as well as to the south-east of England, with relatively low pressure obtaining over the north-eastern part of the North Atlantic and including the Icelandic region.

Summary of Results.

(*a*) Winter appears to be the season during which days of the South-Westerly type are most prevalent.

(*b*) The type is distinctly more cloudy than normal during all seasons.

(*c*) The type is accompanied by extraordinarily low percentages of bad or poor visibility in summer at 13h., 18h., and the following 01h., and by low percentages of such visibilities in spring at the same hours. It is accompanied by high percentages of such visibilities at these hours in winter.

(*d*) The type is below normal in fogginess at all seasons and fairly markedly so in spring and autumn.

(*e*) The type is characterized during all seasons by a much greater number of rain-days than the average.

(*f*) The type is below the average for all seasons with regard to the occurrence of snow or sleet, hail and thunder.

(*g*) The type is seldom accompanied by severe frost either on the ground or in the screen. Moreover, in spring, screen frosts of any description are very unlikely and ground frosts rare; a similar comment applies to autumn, though with less force.

(*h*) The type is seldom succeeded at the following 01h. by a relative humidity less than 81 per cent. during any season; a similar result holds during autumn and winter for 18h. It has, on the other hand, in summer large percentages of relative humidities below 71 per cent. at 13h. and below 81 per cent. at 18h.

Meteorological Characteristics associated with the Northerly Type of Weather at Cranwell, Lincolnshire.

The following is a condensed account of a paper by Messrs. W. H. Pick and G. A. Wright based on an examination of the 07h. synoptic charts published in the *Daily Weather Report* of the Meteorological Office, London, for the period January 1920 to October 1925. By the kindness of the authors the complete MS. is lodged in the Society's Library and is available for reference by those desiring more detailed information than it is possible to give in this brief *précis*.

The pressure distribution which gives rise to a Northerly type of weather at Cranwell occurs when pressure is high to the west and north-west of Ireland and low over Scandinavia and Denmark.

Summary of the Results.

(*a*) Spring and summer are the seasons most favouring the occurrence of the Northerly type.

(*b*) Considering 13h. the type is more cloudy than normal in winter and less cloudy than normal during the other three seasons. Clear skies, *i.e.*, skies with three-tenths or less of cloud, are of very rare occurrence with it in summer.

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(*c*) The type is accompanied by low percentages of bad or poor visibility in spring and summer, it being especially noteworthy that no such visibility occurred at 18h. with it during summer. Spring and summer are marked by high percentages of good or very good visibility at 13h. and 18h.

(*d*) At all seasons the type is below normal in fogginess, very markedly so in winter.

(*e*) The type is accompanied by a less number of rain-days than is normal in winter, summer and autumn, and by a greater number than normal in spring.

(*f*) Snow or sleet days are much above the average in spring and a little above the average in winter. The type is comparatively free from hail in winter, summer and autumn, and is not much marked by thunder.

(*g*) The type is very largely accompanied by frosts both on the ground and in the screen in winter, often so in spring but not so markedly in autumn. Severe frosts, however, are very rare in any season.

(*h*) The type on the whole is one of comparatively low humidity. The exceptions are to be found in summer, autumn and spring at 01h.

A Discontinuity of the Channel on Wednesday, March 24.

The 7h. chart for March 24, 1926, shows moderate to fresh Easterly winds along the English coast, while at Guernsey the wind is SSW force 1. These winds and the slight rain at Portland and the rain at Havre suggest a discontinuity somewhere near the French coast, and as a flight was made to Guernsey on that date by a pilot of Imperial Airways, the opportunity was taken to find out the nature of the weather experienced between Calshot and the Channel Isles. The pilot's report is as follows[1] :—

"While flying from the Needles on a south-westerly course I passed through patches of blue sky alternated with areas of completely overcast sky, where the clouds appeared to be roll-form lying in a SE-NW direction at a height of about 1,500 feet. The wind was Easterly about 25 m.p.h. on the surface, and at 1,000 feet E by S about 30 m.p.h.

"When Alderney lighthouse bore 30° on the port bow, I approached a long roll of dark black cloud at a height of about 1,200 feet lying in a SE-NW direction and extending for several miles. The wind right up to the moment of reaching it maintained its strength and direction, *i.e.*, Easterly about 25 m.p.h. The cloud was very dark and threatening, and I wound in my aerial as I passed under it. The passage was not bumpy, and I soon emerged into sunshine again on the other side, where I found the wind was from SW about 17-20 m.p.h. It is my opinion that the SW wind was passing up and over the Easterly one, because I felt a distinct tendency for the machine to rise. The whole formation appeared to be moving NE.

"On the homeward journey I again passed through this area two hours later. The dark cloud had disappeared, but the wind changed quite suddenly from SW 17 m.p.h. to E 25 m.p.h. and there was again a tendency for the machine to rise just before the change took place. The position of the change had moved about 30 miles further NE during the interval."

[1] The pilot left Calshot for Guernsey at 11.00 h. and arrived at 12.39 h. The return flight was commenced at 14.00 h. and completed at 15.40 h.

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Guernsey reported drizzle and slight rain during the morning. At Colshot there was a good deal of Alto-Stratus, but this cleared away rather quickly about 15h.

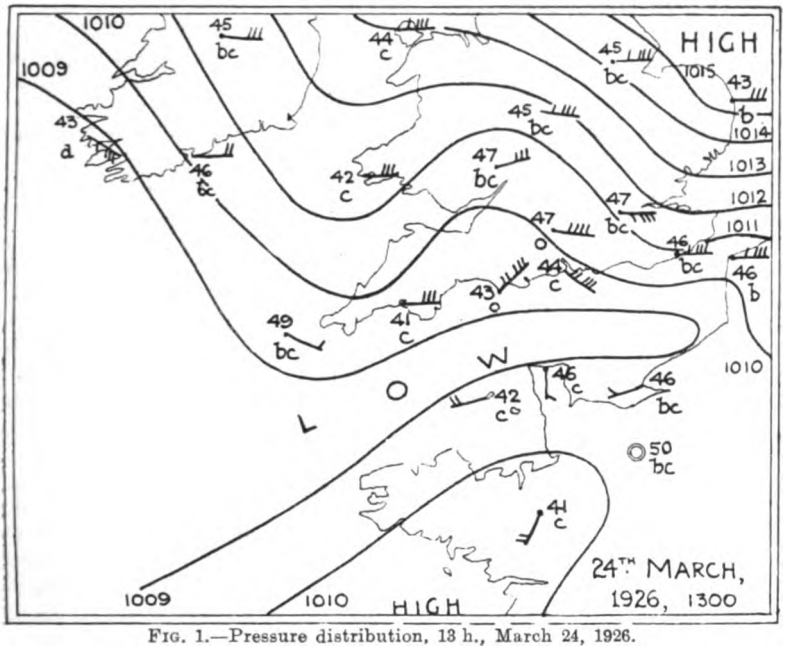

FIG. 1.—Pressure distribution, 13 h., March 24, 1926.

The 13h. chart for March 24 shows more clearly the existence of the discontinuity along the English Channel and its passage north-eastwards can be traced on successive charts until 18h. of March 25. During its travel across Kent and further north-east, sufficient observations exist to locate a small depression. The autographic records show the times of passage were approximately as below :—

Croydon, 13h. March 25.
Felixstowe, 15h. March 25.
Gorleston, 20h. March 25.

No rain was reported during the passage, but it was accompanied by very low cloud. At Croydon the cloud height from 7h. to 9h. was 225 feet, but lifted gradually to 450 feet at 10h. and then rapidly, decreasing in amount at 11h.

At Biggin Hill the clouds were below 150 feet for the period 7-10h., but the cloud base lifted at 13h. and the clouds also decreased.

No special phenomena were reported from Lympne, where the wind remained throughout SSW-SW, although the cloud base fell to 450 feet at 8h. but lifted again by 9h.

Calshot. J. DURWARD.
March 29, 1926.

Abstracts of Papers on the Meteorological Relations of Atmospherics.

In June, 1923, the Council received a letter from Mr. R. L. Latcham, of the cable steamer "*John W. Mackay*," Nova Scotia, calling attention

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to the possibility of using, for the purpose of weather forecasting, observations of the character of those naturally occurring electromagnetic waves, called atmospherics, which are so familiar to all wireless listeners. The Council appointed a small committee to consider whether observations on atmospherics might be of service in forecasting. As a preliminary to the work of the committee, the writer undertook to prepare the bibliography of the meteorological relations of atmospherics which is now reproduced here.

The correlation between the occurrence of actual thunder or lightning and the radiation of atmospherics is so well known that many references to it have been omitted, but it is believed that no other well authenticated data have been overlooked.

It will be seen that very acute divergences of opinion exist as to possible relations between the intensity of atmospherics on the one hand and most of the phenomena definitely recognised as "meteorological" on the other. There is an overwhelming consensus in favour of the obvious correlation with thunder, moderate agreement on the correlation with convective processes in the absence of reported thunder, but beyond this point, the evidence is mutually contradictory. Reasons for this are not difficult to assign. It is established beyond doubt that the range of reception for atmospherics may reach one or two thousand miles, it is most probable that the range frequently, if not usually, attains the length of the earth's semi-circumference. Comparisons between received atmospherics and local weather will therefore, in part, be a comparison of the weather of a parish with the electrical phenomena of a hemisphere. Moreover it is still impossible to find a scale and a classification for the intensity and character of atmospherics which shall be generally acceptable, unambiguous, and capable of assessment by the average observer. The Beaufort of atmospherics is not yet.

Nevertheless, the evidence that the atmospheric was well, if rashly, named is accumulating rapidly, and the summaries of the most recent work show that the location of "cold fronts" by radiotelegraphic observations on atmospherics is an established possibility.

R.A.W.W.

Jackson, H. B.—*London, Proc. R. Soc.*, **70**, (A.), 1902, p. 266.

After describing typical X effects from lightning, remarks that X's are more frequent in summer and autumn than in winter and spring, near high mountains than in open sea, in South than in North winds (in the Mediterranean), in the front of a cyclonic disturbance than in the rear, with falling barometer than with rising barometer.

Notes case of a heavy winter gale, without observed lightning, which was preceded by X disturbance.

Crawley, C. G.—*London, Elect.*, **69**, Jan. 31, 1913, p. —.

X's in Mediterranean are worst when pressure is low, temperature high, and humidity low. The sirocco forms an exception to this rule, as it always brings atmospherics.

Erskine-Murray, J.—*London, Elect.*, **67**, 1911, p. 219.

Describes observations showing that every observed lightning flash produces an X, multiple flashes producing multiple X's, and discusses the adequacy of the known thunderstorm distribution to account for all X disturbance. The author proposes direction-finding for the location of X sources.

Esau, A.—*Phys. Zeit., Leipzig*, **12**, 1911, p. 799.

In observations at Halle 1908-11, with crystal detector on plain aerial, X's were found to increase with increase in atmospheric transparency, wind

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velocity, cumuliform cloud and with decrease in relative humidity; to decrease with increase of non-cumuliform cloud, dust content, fog (in which X's reached very low values); and to be variable and indeterminate during precipitation.

Loring, F. G.—*London, J. Inst. Elec. Engin.*, 1911, p. —.

X's are noted as accompanying heavy rain, an East wind on the east coast of England, or a North-west wind in Ireland.

Mosler, —.—*Elek. Zs., Berlin*, **33**, 1911, p. 1134.

As a result of observations from August 1911 to July 1912, X's are stated to increase with cloud at the receiving station, and to be severe when the potential gradient is high, especially when it is varying rapidly. X's were found to be relatively slight under a uniform cloud sheet, in rain and in fog.

From the fact that no sensible change in X disturbance was noted when thunderstorms were occurring over Böhmen and Saxon Switzerland, the author concludes that lightning does not propagate X's sensibly beyond a 200 km. range.

The high X activity near mountains is referred to the prevalence of cloud and to the high potential gradient.

Round, H. J.—*Marconigraph, London*, **2**, 1912, p. 310.

Finds minimum of X disturbance within one minute of sunset, and considers this to be due to minimum air turbulence then.

Flajolet, —.—*Paris, C.-R. Acad. sci.*, **154**, 1912, p. 729.

Describes the recording of thunderstorms up to 500 km. distance by crystal detector and galvanometer.

Eccles, W. H.—*London, Rep. Brit. Ass.*, 1912.

Timing of lightning in Transvaal and X's in England indicates that the former is a source, but not a main source, of the latter.

Franck-Duroquier.—*Nature, Paris*, **41** (1), 1913, p. 218.

On the basis of one year's observations at Anché (Indre et Loire) the relations between X's and weather are thus enunciated (the original French descriptions being retained to avoid ambiguity by loss of onomatopœia).

(1) Violent "*craquements*" indicate a thunderstorm, approaching if the X's become more and more frequent, receding if they become less frequent or less strong.

(2) A slight "*sifflement*" is produced by a heavy hailstorm passing near the receiver.

(3) Dry, isolated, and rather weak "*claquements*" generally precede a fall of temperature, a spring frost.

(4) If the wind is about to turn, the X's are of short wave-length, and seem to come in strings.

(5) Numerous "*crépitements*," accompanied by fairly regular strong and "*fusant*" "*craquements*," precede great barometric depressions and foretell gales.

(6) The approach of rain, snow, or fog, by increasing the conductivity of atmosphere and ground, facilitate radio communication. Dryness and cold, on the contrary, impede it.

Lutze, —.—*Phys. Zeit., Leipzig*, **14**, 1913, p. 1194.

Finds that X's and changes of recorded potential gradient go together. Balloon observations show great increase of X's inside cloud, and a rapid decrease of X's with increasing height.

Delval, —.—Quoted in Perret Maisonneuve's "*La T.S.F. et la Loi*," (1914).

Observations at Mt. St. Aubert, Tournai, May-September, 1912, led to the following conclusions:—Absence of X's characterizes approach of fine weather; little precipitate cracklings—hail or heavy rain; distant cracklings—fine weather; numerous and prolonged cracklings—stormy weather; prolonged sound like water from a gutter—sudden change of weather; prolonged and singing sound seeming distant at first, approaching little by little till strong—violent thunderstorm or tempest.

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Marriott, R. H.—*Proc. Inst. Radio Engin., New York*, **2**, 1914, p. 37.

An outburst of X's follows a sudden change of wind on the North Atlantic coast of the United States, especially a change from South to North. X's also accompany a rise of temperature there.

Curtis, —.—*Proc. Inst. Radio Engin., New York*, **2**, 1914, p. 37.

Would explain the annual variation of X disturbance by the oscillation through several hundred miles north and south of the Equator of the tropical thunderstorm belt.

Radiotelegraphic Investigations Committee of the British Association. *London, Rep. Brit. Ass.*, 1915.

X storms coincide with convective weather, rapid fluctuations of pressure, and rapid movements of depressions.

In Malta, X's precede by several days the advent of convective weather.

In Australia, day-time rain is preceded by X's in 80 per cent. of all cases.

In Ireland X's are bad with a North-West wind on the Atlantic coasts.

In Sierra Leone the periodic dry wind suppresses X's.

De Groot, C. J.—*Proc. Inst. Radio Engin., New York*, **5**, 1917, p. 75.

Classifies types, based on observations in the Dutch East Indies:—

(1) Clicks, from near or distant lightning, but of "range certainly less than 900 km."

(2) Hiss, an intermittent direct current from the aerial, when low charged clouds pass over the station.

(3) A continuous rattle, always present in East Indies, unfamiliar in Europe. Faint in the morning, strong in the afternoon, as strong or stronger at night. In the West trade or monsoon (3) often accompanies heavy thunderstorms, but the maxima of (1) and (3) are not in general coincident. (3) is ascribed to bombardment of the upper atmosphere by cosmic particles.

Culver, —.—*Philadelphia, Pa., J. Frank. Inst.*, **187**, 1919, p. 529.

Observations on 14,000 metre wave-length with bent aerials 100 ft. long and 15ft. high directive to France, at several American stations, give the following results:—

PRESSURE, no agreement, but X's bad with an anticyclone off Newfoundland.

WIND, no agreement with direction, but tendency for variation inverse to velocity.

SOIL TEMPERATURE, no conclusion.

AIR TEMPERATURE, audibility of X's low when temperature at or above normal value.

CLOUD, no relation save in thunderstorms.

ABSOLUTE HUMIDITY, no relation.

RELATIVE HUMIDITY, audibility of X's and relative humidity directly related.

POTENTIAL GRADIENT, audibility low with high positive potential gradient. No conclusion in the few negative gradients examined. X's are bad when recorded potential gradient is fluctuating rapidly.

TERRESTRIAL MAGNETISM, X's found to be directly related to H. and V.

SOLAR CONSTANT, inverse relation.

Goldschmidt, R.—"*La Telegraphie sans Fils au Congo Belge*," (Brussels, 1920).

From observations in the Belgian Congo, 1915-17, the author believes that X's from lightning have an effective range not exceeding 100 or 200 km.

In general a day of thunderstorm is preceded by several days of increased X disturbance.

In general a day of thunderstorm is followed by several days of reduced X disturbance. This law is more general than the former.

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Telegraphentechnischen Versuchsamt. *Jahrb. Telegraph. Versuch., Berlin*, **16**, 1920, p. 219.

No relation between X's and convection or potential gradient was traced save when a thunderstorm was occurring or threatened.

Keyser, —.—*Washington, D.C., U.S. Dept. Agric., M.W. Rev.*, 48, 1920, p. 263.

Notes the application of radio direction-finding on atmospherics to the study of tropical storms.

Wiedenhoff, S.—*Jahrb. drahtl. Telegraph., Berlin*, **18**, 1921, p. 242.

Low X intensity is found under rainless cloud, X's increase as cloud begins to break up or as rain begins. Diminishing convection current goes with low X intensity.

From a comparison of annual variation curves the author summarises as follows:—X maxima go with low potential gradient, but high convection current and high numbers of ions per c.c., and conversely for X minima.

From diurnal variation curves:—X's are bad when the vapour pressure is at a maximum at the surface and increasing above, when the conductivity at ground and aloft is increasing, and the surface wind decreasing. X disturbance is at a minimum with maximum conductivity at a moderate height, with overcast sky, with maximum relative humidity, minimum temperature, and maximum air pressure.

Marchand, —.—*Rev. Gen. sci., Paris*, 32, 1921, p. 594.

Increased X frequency indicates an imminent thunderstorm, if the intensity of X's is great the thunderstorm will be violent, with wind and rain, if the X intensity remains low the thunderstorm is feeble. If the intensity augments the storm is approaching, and vice versa.

This diagnosis is valid at great distances, before the cloud associated with the storm has appeared at the receiving station.

Direction-finding on storms is referred to.

Winter gales, and in general all gales affecting the North Atlantic, are " not electrical but cyclonic," and do not perceptibly modify X conditions.

Rothé, E.—*Paris, C.-R., Acad. sci.*, **175**, 1921, p. 840.

Infrequent but sustained X's with an intense high metallic note are due to more or less distant cloud. Visible lightning, and hail, give this type of X.

Lacoste (*q.v.*) is summarised.

Lacoste, J.—*Paris, C.-R. Acad sci.*, **175**, 1921, p. 843.

Enunciates laws based on radiogoniometric observations at Strasbourg.

(1) If a distinct well-developed depression exists, with closed concentric isobars, the maximum X disturbance proceeds from the south or south-east of the depression, the displacement in direction and variation of intensity allow of following the course of the depression.

(2) If the depression has a distant centre and less curvature, the X maximum is still south or south-east of the periphery, but is less sharply marked.

(3) Secondary depressions, with " barometric pockets " and cols, correspond to storm fronts, the direction of X maximum is difficult to find, and X's are violent from all azimuths.

(4) A near thunderstorm gives violent X's from its azimuth.

Many X's received in clear weather are comparable in intensity to those of observed lightning. The author concludes that X's are due to more or less distant storm phenomena, and are often produced in overcast regions.

The last few days work in the period in question indicates that fog facilitates X transmission.

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Rothé, E.—*Ann. Phys., Paris*, **17** [1921], p. 385.

X's come from definite azimuths when storm clouds are distant, but are observed on all azimuths when the storm is very near.

Storm clouds produce X's which gradually cease as soon as uniform rain starts, but X's persist to some extent when rain is violent.

Strato-cumulus most often furnish well-defined and oriented rumbling X's.

Re-summarises Lacoste, *q.v.*

Lacoste, J.—*Paris, C.-R. Acad. sci.*, **176**, 1922, p. 707.

Describes further work at Strasbourg in summer of 1922, confirming previous conclusions, and demonstrating possibility of forecasting new depressions. Remarks on the special value of the radiogoniometer in thunderstorm forecasting.

Some thunderstorms give X's which are numerous only on short wave observations.

Esau, A.—*Jahrb. drahtl. Telegraph., Berlin*, **19**, 1922, p. 258.

Recognises three classes of X's, according to origin and character.

(1) Separate impacts in very quick succession, of marked directivity ascribed to the influence of solar radiation. These X's start at sunrise, reach a maximum in the afternon, and decrease very rapidly towards sunset.

(2) Distinctly separated simple impacts appear after sunset, grow in intensity as night proceeds, and disappear as morning twilight approaches. These show little directivity.

(3) Besides these regular disturbances, a third variety originates in thunderstorms.

Watson Watt, R. A.—*Nature, London*, 1922, p. 680.

Preliminary results of directional observations on atmospherics during 1916-18, by stations on British coasts, show that on an average five apparent sources of atmospherics per week were located. Of those checked against meteorological data, 15 per cent. agreed with reported thunderstorms, 10 per cent. with squall phenomena, 69 per cent. with rainfall within the 24 hours containing the time of observation, without reported thunderstorms or squalls. Thus 94 per cent. of the apparent sources were associated with rainfall. Thirty-five per cent. of the cases examined fell on the forward edge of a rain area.

Wolf, F.—*Jahrb. drahtl. Telegraph., Berlin*, **19**, 1922, p. 289.

Gives results of observations at Heidelberg, September 1919-August 1921, on 2,000 and 12,500 metre wave-lengths. In the warm half-year X's developed on the appearance of a new depression over North-West Europe, disappeared on its departure or filling up.

No close relation between X's and depressions was traced in winter. Even winter thunderstorms often failed to give a notable increase in X disturbance.

Stoye, K.—*Jahrb. drahtl. Telegraph., Berlin*, **20**, 1922, p. 303.

Observations in the plains of Upper Rhineland, 1915-17, on 600 to 2,000 metre wave-lengths, led to a classification of X's in ten groups.

(1) Prevailing weather type, a whistling sound decreasing in strength, ending almost in a whisper.

(2) Mist type, weak hissing sound.

(3) Cloud break-up type, repeated groups in the form of explosive crashes. Specially marked on break-up of alto-cumulus.

(4) Cirrus type, " trrrrtasss " (palatal r.), increasing as cirrus gathers, continuing till cirrus ceases to increase.

(5) Lightning type " rrrrrrrsss " (palatal r.), a more rapid " r " succession than in (4).

(6) Front type (squally wind), creak like a revolving clapper.

(7) Cumulus-development type, short single sharp cracks.

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(8) Thunderstorm-cumulus type, sharp cracks of different strength, coming in groups.

(9) Sunrise type, violent rattling and scratching of longer duration, not in group form.

(10) Sunset type, superposition of (3), (9) and other types, partly due to surface cooling and condensation, partly to cloud break-up.

Every stage in the development of a thunderstorm released a definite type of disturbance. Groups 4 and 8 are superposed in thunderstorms.

The lightning type was observed at night with perfectly clear sky.

The increase in disturbance numbers started several hours before the onset of the thunderstorm, though there were exceptions to this rule.

In spite of unmistakable signs of thunderstorm the number of disturbances remained normal until a sudden release occurred.

Strong disturbances were found to come from strata of misty haze and also from forests with their well-known summer cloud formation.

Direction-finding differentiated between sharply directed X and those showing little directivity. Localized thunderstorms and squalls could be located in azimuth.

Cave, C. J. P., and **Watson Watt, R. A.**—*London, Q.J.R. Meteor. Soc.*, **49**, 1923, p. 36.

Discuss the early history of direction-finding on atmospherics as applied to the location of thunderstorms.

Watson Watt, R. A.—*London, Wireless World and Radio Rev.*, **12**, 1923, p. 601.

Summarizes work on X's under the Meteorological Office and the Radio Research Board, gives examples of the location of thunderstorms up to 2,400 km. distant, by direction-finding on X's, and discusses the relations of X's, rainfall, and lightning.

Herath, F.—*Zeit. Tech. Phys., Berlin*, **3**, 1923, p. 116.

The different reception disturbances are discussed separately:—

(1) Short distinct impacts or crackling noises are to be ascribed to near or not very distant lightning discharges. They are directional and interfere very little with reception. For receiving America directionally in Germany, the most favourable locality is the north part of Schleswig-Holstein, according to the map showing the frequency of the occurrence of storms.

(2) Loud rattling noises arising from highly charged precipitation (rain with wind, hail, sleet or snow) in the immediate neighbourhood of the antenna.

(3) Continual hissing, only perceived in this part of the world in the case of conductors reaching very high up (kites, mountain stations), comes from the glow discharge with low, highly charged clouds.

(4) The most frequent disturbance—a crackling sound—is produced through electrical equilibrium phenomena taking place between the smooth, ascending and the interrupted, descending surfaces, and which therefore is loudest when stratification of this character is present in the open atmosphere directly over the receiving aerial.

Such stratification and convection currents can also arise with a cloudless sky through intense solar radiation. Continual and tropical stations are more exposed to this kind of disturbance than coast stations.

Kiebitz, F.—*Jahrb. Telegraph. Versuch., Berlin*, 1923, p. 196.

Refers to Telegraphentechnischen Versuchsamt results (*q.v.*).

Gherzi, E.—*Onde Elect., Paris*, 1924, p. 491.

Experiments fail to reveal any correlation between direction of arrival of X's at Shanghai and position of typhoons. Cyclonic centres can be located and followed in winter and spring, thunderstorms being fairly frequent in the SE quadrants of such formations. In typhoons such electrical phenomena are rare. Despite the downpours of rain in typhoons, no X's appear to be generated. Typhoon postulated as formed solely in equatorial air to explain this electrical quiet.

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Bureau, R., and others.—*C.-R. Acad. sci.*, **178,** 1924, p. 556; 1623; **179,** 1924, p. 394; **180,** 1925, p. 529; 1122; *Onde, Elec.*, **4,** 1925, p. 31; 58.

This series of papers is best abstracted as a whole, it is concerned with the correlation between X disturbance and invasions of polar air.

The first paper states that from earlier directional data by others it is seen that X's always appear to come from regions over which a mass of fresh polar air is passing. X's from thunderstorm zones are a particular case of this.

Comparison of X disturbance and meteorological conditions shows X increasing when polar air passes over high mountains (Alps), *e.g.*:

November 7th, 1923. Cold front reached Alps in first half of night, followed by secondary rain cloud at 7 h., and a new cold front later in day. X's bad in France 1 h. to 3 h., fell off during day, and again increased at 18 h.

November 22, 1923. The worst day for X's in November and December, was most disturbed at 8 h. and again, more severely, between 18 h. and 20 h. These times correspond to arrival of, and complete establishment of, a cold current. X's disappeared somewhat suddenly in night of 22nd-23rd, when system became warmer and more humid.

Second paper asserts that the more marked relation thus traced in winter, as opposed to summer, is due to the need for vigorous reinforcement of winter fronts before they become troublesome, while summer fronts are sufficiently vigorous in themselves to give general disturbance without orographic reinforcement. At all seasons any increase in X disturbance is due to cold fronts. High potential energy of fresh polar air is degraded in all ways, kinetic (Cu. Nb. and squalls), electric (thunderstorms and X's), and by temperature equalization.

Instability is accentuated orographically by forced ascent, and reaches a maximum when the adiabatically cooled polar air crosses the summit and meets the air which has been warmed by the plain beyond. A phenomenon similar to this winter one is the warm season phenomenon in SW France, when cold fronts after crossing the Spanish plateaux and being reinforced by adiabatic cooling meet air warmed by contact with the Bay of Biscay and the ground.

Third paper cites, *e.g.*, May 14, 1924, cold front crossing Pyrenees slowly spreading over S.W. France, reaching Paris in beginning of night; followed by long thunderstorm period. On X side, some days of comparative quiet were followed by violent X's on evening of 13th at stations in W and SW France. At Paris maximum disturbance was from S on morning of 14th, followed by disturbance in all azimuths. This persisted, save for two short intervals, to end of month.

Cold front had produced X's before reaching France because reinforced by crossing Pyrenees, which favoured persistence of disturbance by energetic cooling at a height, while ground temperature is relatively high. Cold fronts arriving further north produces violent X's, but for a short time only, followed by calm.

Third paper sums up thus:—In our latitude at *all seasons*—

(1) X's invariably linked with cold fronts, even when these do not produce thunderstorms.
(2) They are put an end to by warm fronts.
(3) They are reinforced when cold front ascends mountainous country.
(4) They are also reinforced when cold front spreads over regions of high ground temperature.
(5) (3) and (4) together may give rise to persistence over long periods.

Fourth paper summarizes eleven months' observations, stated to confirm and amplify previous conclusions. The main additions are:—

(*a*) A statement of diurnal variation in May; X's start at noon, increase to 21 h., diminish, and reach secondary maximum at 4 h.

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(*b*) June and July phenomena of cold fronts with characteristic discontinuities of temperature and wind, but with no thunderstorms or showers. Neither do they produce X's so violent, numerous, or general as when front produces cloud or precipitation.

Range of reception of X's estimated, from examples cited, at 30 to 35 k.

Fifth paper classifies X's in two types:—

(1) Migratory, related to normal polar front, and characterized by alternate appearance and disappearance due to cold and warm fronts, absence of daily periodicity, azimuthal disymmetry, and temporal disymmetry. Latter thus: Before passage of front, short isolated discharges, increasing in frequency and intensity, changing to prolonged cracklings after front passes. If front passes as line squall, brief calm between pre-frontal and post-frontal types.

(2) Stagnant, related to pseudo polar fronts, characterized by appearance and disappearance linked with establishment and decay of disturbance current over France; no alternations of X's to correspond to alternations of centres of rise and fall of pressure; very distinct diurnal periodicity (appearance about 11 h., disappearance about 21 h.); almost simultaneous appearance and disappearance over all France, only directional effect being cum-solar swing; extreme and uninterrupted violence, rollings for hours on end; absence of azimuthal disymmetry.

Fifth paper thus sums up:—

In the different branches of the polar front, electro-magnetic energy only appears with invasions and (especially) expulsions of polar air. In pseudo fronts it is manifested violently at the same time at every point. The release is not brought about solely by discontinuities, origin and history of air masses have influence, polar air of cold fronts may have discharges unknown in equatorial air, while latter, between noon and night is the constant theatre of sudden ruptures of electro-magnetic equilibrium.

Sixth paper deals with observations on a transatlantic voyage of the "Jacques Cartier." Approach of cold front is preceded by appearance of X's 400 miles ahead at night, 250 miles by day, increasing till front passes, then frequently a lull for some hours. This temporary lull corresponds to appearance of sky, Cu. Nb. being replaced by St. Cu., but X's reappear in centre of pressure rise. Final disappearance is determined by a centre of fall or warm front.

Double fronts are accompanied by X's which are more severe the more pronounced the meteorological discontinuity.

These phenomena remain the same in low latitudes, X's there are in general governed by the disturbances of the polar front or their prolongations, the equatorial air of warm sectors even of very low latitude depressions has no X disturbance. Radical disappearance of X's was experienced in the south-east sector of a tropical cyclone (*cf.* Gherzi). On the other hand extensions of cold fronts or double fronts into the sub-equatorial regions produce a violent increase of X's felt hundreds of miles ahead of front.

"Atmospherics are the phenomenon that best gives evidence of the passing of meteorological disturbances in tropical regions; the other meteorological variables only indicate that passing in a much less regular way; moreover, they only give evidence of the meteorological disturbance when it has reached the observing station, while atmospherics announce it some hours in advance."

Gockel, A.—*Zeit. Hochfrequenztech.* 131 (May) 1925.

Herath's (*q.v.*) kite experiments show that when layers of low conductivity were over the observatory, X's were heard, thence he concluded that the boundary phenomena of these layers caused X's. Meissner goes further, and conjectures that these boundary phenomena at inversion strata or gliding surfaces are a gigantic source of generation of electricity. This was violently opposed at the Innsbruck conference (Autumn 1924). The author's experiments support Herath as to the coincidence between X disturbance and the approach of Föhn weather.

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Lugeon, J.—*Paris, C.-R. Acad. sci.*, **180**, 1925, p. 594.

Observations at Lausanne 1919 to 1922, at Zurich 1924.

X disturbance differs in plain, valley and mountain, correlation with the continental meteorological situation is difficult, but a direct relation with electrical conditions and weather in Alps and Jura appears. Every important change in disturbance appears to correspond to a change in vertical temperature gradient.

Equatorial air from the West, impinging on summits of 3,000–4000 m., carries beneath it a zone of great increase of X's, while high mountain stations record considerable diminution. When the surface of discontinuity reaches heights of Jura, crepitations and rollings are at a maximum on plateau and in valley. They then rapidly diminish, sometimes cease, but begin again feebly near the rain zone which is characterized by clicks. A little later the régime is uniform at all amplitudes.

The passage of cold fronts, lines of occlusion, or pseudo-fronts gives different and less distinct phenomena. On slow air-exchange rates, it has not been possible to determine whether any influence on X disturbance exists. The discharges are numerous, diverse, and strong on the average, diminishing in the precipitation zone. With a steeper cold-front gradient, disturbance precedes by 100 or 150 k. the ascent of cold masses in the Jura. X's increase rapidly from the moment this first barrier is passed, and rapidly invade the plateau, but remain weak at heights. They reach the heights an hour or two before the change of sign of the temperature gradient. The partial temperature inversion frequently characterizing this process is a sure sign of electrical instability. As soon as equilibrium is re-established X's diminish, the diminution beginning at the lower levels.

Directional observations showed direction of X disturbance in closed valleys to coincide with the discluding sense of the valley before a temperature fall, and with its ascending sense in Föhn weather or temperature rise.

A station 2,000 m. above a valley station recording many X's showed practically no X's till itself immersed in cloud masses condensed by the deepening stream of cold air. In winter anti-cyclones, with strong temperature inversions, the plateau is covered by the high mists of strato cumulus. This seems to screen the plateau from distant X's recorded at heights.

Preliminary conclusions are stated thus:—

(1) Intensity frequency nature and direction of X's vary with altitude.

(2) This variation is closely connected with variations of vertical temperature gradient. Cooling augments, heating diminishes the phenomenon.

(3) Lower layers are much more disturbed than higher.

(4) Apart from X's of proved distant origin, range of X's originating in the lower layers does not seem to exceed 250 k., and remains almost always under 150 k. in mountainous regions.

Watson Watt, R. A.—*London, Proc. Phys. Soc.*, **37**, 1925, p. 230; *London, J.R. Aero. Soc.*, **29**, 1925, p. 170.

Shows correlation between apparent sources of atmospherics and their meteorological environment. Of 490 cases examined, 25 per cent. fell within 250 k. of reported thunder, a further 28 per cent. were associated with more distant thunderstorms or with squall phenomena, 21 per cent. more with rain, 13 per cent. more fell on barometric minima, leaving 13 per cent. uncorrelated.

Reports the tracking of a cold front for 2,700 k. by automatic recorders of X's.

The compiler of the bibliography desires to acknowledge his indebtedness to the Radio Research Board for giving facilities for the work, and to Miss D. E. Harvey, B.Sc., translator and abstractor to the Board, whose admirable abstracts of current radiotelegraphic literature have lightened his task.

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TABLE I.—Summary of Conclusions by Different Observers as to Meteorological Relations of Atmospherics.

Observer. In approximate order of publication.	Approx. Date of Observations.	Place.	Pressure.	Temperature.	Increase of Temperature.	Relative Humidity.	Absolute Humidity.	Rainless Cloud.	Cloud.	Rain.	Fog.	Visibility.	Dust.	Wind Direction.	Wind Velocity.	Air Turbulence.	Convection.	Thunderstorms.	Potential Gradient.	Increase of Pot. Gradient.	Terrestrial Magnetism.	Magnetic Storms.	Aurora.	Depressions.
Jackson	1902	Mediterranean	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	+	...	...	...	...	...	+
Schwartzhaupt	1910	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Loring	1911	Great Britain	...	...	...	...	...	...	...	+	...	...	...	Inshore	...	...	...	...	...	...	...	...	...	..
Esau	1908-11	Germany	...	...	...	—	...	—	+	...	—	+	—	...	+	...	...	...	...	...	...	...	...	...
Erskine Murray	1911	Gt. Britain, etc.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Taylor	1911	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	...	...
Round	1912	do. and Atlantic	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...
Delval	1912	France	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Mosler	1911-12	Germany	...	...	...	...	...	—	+	—	—	...	...	...	...	...	...	+	+	+	...	...	...	...
Lutze	1913	Germany	...	...	...	...	...	Uniform Sheet + Inside	...	...	...	...	...	.	...	...	...	...	δ	...	...	...	...	...
Duroquier	1913	France	...	...	—	...	...	...	...	...	...	...	...	δ	...	...	+	+	...	...	...	...	...	...
Marriott	1914	U.S.A.	...	...	+	...	...	...	...	...	...	...	...	δ	...	...	...	...	...	...	...	...	...	...
Curtis	1914	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
B.A.Commission	1915	Gt. Britain, etc.	δ	...	...	...	...	...	...	+	...	...	...	Inshore	...	...	+	+	...	...	...	...	o	...
De Groot	1917	Dutch E. Indies	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	+	...	...	...
Eccles	1912-19		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Culver	1919	U.S.A.	o	—	...	+	o	o	...	...	...	...	...	o	—	...	...	+	—	+	+	...	...	...
Telegraphen Tech. Vers.	1920	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	o	+	o Save Ts	...	...	...	...	...
Brooks & Lyman	1920	U.S.A.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	o	...
Goldschmidt	1915-17	Belgian Congo	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Rothé	1921	France	...	...	...	...	...	+	+	—	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Wiedenhilf	1921	Germany	—	+	...	-	+	—	...	+	...	...	...	...	—	...	+	...	—	+	...	...	...	...
Lacoste	1921	Alsace	...	...	...	...	...	...	...	...	+	...	...	...	...	...	+	+	...	...	...	...	...	+
Bouthillon	1921		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Wolf	1922	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	Hum	In + Summer
Crawley	1908	Mediterranean	—	+	...	—	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Marchand	1921	U.S.A.	...	...	...	...	...	...	...	...	...	...	...	...	—	...	...	+	...	...	...	...	...	...
Watson Watt	1916-18	Great Britain	...	...	...	...	...	...	...	+	...	...	...	...	...	...	+	+	...	...	...	...	...	+
Stoye	1915-17	Germany	...	...	...	...	..	+	...	...	+	...	...	...	...	...	+	+	...	...	...	...	...	...
		Relation to change of element δ	1	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	1	—	—	—	—	—
		No relation o	1	—	—	—	1	1	-	—	—	—	—	1	—	—	1	—	1	—	—	—	2	—
		Direct relation +	—	2	1	1	1	3	3	6	2	1	—	—	1	1	8	19	1	3	2	—	1	4
		Inverse relation —	2	1	1	3	—	3	—	2	2	—	1	—	3	—	—	—	2	—	—	1	—	-

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Light Filter Measurements made by the Polish Solar Radiation Expedition to Siam in 1923, and at Touggourt in the Sahara Desert 1924.—Dr. Ladislas Gorczynski.

Introduction.

The Council are indebted to Dr. Ladislas Gorczynski, the Director of the Meteorological Service of Poland, for permission to print the following abstract from an important paper[1] giving an account of the observations of solar radiation made with light filters by a Polish Expedition, headed by Dr. Gorczynski on a voyage from Europe to Siam through the Red Sea and Indian Ocean in 1923, and at Touggourt in the Sahara Desert in 1924.

The measurements in 1923 were chiefly made with bimetallic actinometers, over 40,000 observations being made in the period March to August, either on board ship or on the plains and mountains of the equatorial region. For the observations at Touggourt a self-registering instrument was also employed, in which a Moll thermophile[2] was automatically directed towards the sun, the thermo-electric currents thus induced being recorded by self-registering milli-voltmeters of suitable form.[3] Eighty couples of manganin-constantin were employed, which, with an intensity of radiation of one gram calory per square centimetre per minute, gave an E.M.F. of about 20 milli-volts. A spectro-heliograph was also constructed in which the sun's rays, after passing through a prism of special flint glass, rock salt or fluorite, reached a linear thermopile, the thermo-electric currents being recorded by means of a mirror galvanometer and a photographic registering apparatus. The prism was rotated slowly by means of clockwork mechanism, the solar spectrum thus passing in front of the slit of the thermopile in about ten minutes. A portable form was constructed later (in 1925).

Approximate results as to the changes in intensity in the different parts of the spectrum were at first obtained by means of light filters used in conjunction with actinometers, both during the voyage to Siam and at Touggourt.

The filters employed were four in number:—

1. Red Jena glass (F.4.512), which transmits from the yellow well into the infra-red.
2. "Marble" glass, opaque to visible rays, used for the infra-red part of the spectrum.
3. A yellow—a solution of potassium bichromate.
4. Blue—a solution of copper sulphate.

The red filter was 3.95 mm. thick and transmitted more than 80 per cent. of the total intensity between wave-lengths of 0.8μ and 2.5μ. It showed a rapid diminution towards the yellow, being opaque for wave-lengths of 0.54μ or less. In the infra-red the transmission fell off from 55 per cent. at 2.8μ to zero at 4.4μ. The coefficient of transmission,

[1] For a more detailed account of some of these observations reference may be made to a paper by the same author, "Memoirs de l'intensité totale et partielle du Ravonnement solaire effectuées en 1924 en Afrique Nord," *Annales du Service Botanique de Tunisse*, May, 1926, pp. 1-59.

[2] First demonstrated at a Congress at Delft in 1913. See also Moll, W. J. H., "A thermopile for Measuring Radiation," *Proc. Phys. Soc. London*, **35**, part 5, p. 257.

[3] See Gorczynski, Lad., "On a Simple Method of Recording the Total and Partial Intensities of Solar Radiation," *Washington, Monthly Weather Review*, 1924, June.

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TABLE I.—PERCENTAGE OF THE INFRA-RED AS COMPARED WITH THE TOTAL INTENSITY OF SOLAR RADIATION AT TOUGGOURT, APRIL, 1924.

	April, 1924.																							
	1.		2.		3.		4.		5.		8.		9.		10.		11.		12.		13.		14.	
	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.
Atmospheres.	%		%		%		%		%		%		%		%		%		%		%		%	
1.2	14	14	14	...	14	...	14	...	15	...	...	...	13	...	14	15	14	...	14	...	14	14	15	...
1.4	...	...	...	...	...	14	...	15	14	15	15	...	...	14	...	...	...	14	15	...	...	...	15	...
1.6	...	...	14	...	...	...	...	...	...	...	...	...	14	...	...	...	...	...	...	15	...	...	...	...
1.8	...	16	...	...	...	15	...	...	15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16
2.0	15	...	15	...	15	...	15	...	...	...	...	...	...	...	15	...	15	15	15	...	15	15	...	...
2.5	...	...	...	16	...	...	...	...	16	..	...	...	...	...	. .	...	...	...	...	...	...	16	...	...
3.0	...	...	...	...	...	16	...	...	...	...	16	...	...	..	...	16	16	...	...	16	...	...	...	17
3.5	...	17	16	...	...	...	...	...	...	18	...	...	16	...	...	...	...	...	17	...	16	...	16	...
4.0	...	...	...	...	...	...	...	...	17	...	...	...	...	...	16	17	...	...	...	...	...	...	...	...
4.5	...	...	17	...	...	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	...	...	18	17	17	...	...	...	...	...	...	...	...	17	...	...	17	17	18	...	17	...	...	...
6	17	...	...	...	...	...	19	...	...	...	18	...	17	...	...	...	18	...	...	...	...	...	...	19
7	18	...	19	...	...	...	21	...	...	...	...	...	...	...	20	...	. .	19	...	...	...	...	...	...
8	...	20	...	...	20	20	...	...	21	...	19	...	19	...	...	20	...	...	20	...	...	20	19	...
9	19	...	...	...	...	...	22	...	...	...	...	...	...	...	...	...	...	20	...	...	22	...	...	...
10	...	...	22	...	...	...	...	...	22	...	...	...	20	...	21	...	21	...	...	...	...	...	...	...
12	20	...	...	...	...	22	23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...	...	24	...	...	...	...	...	...	22	...	...	22	...	23	...	...	24
16	...	...	...	...	...	...	...	...	...	...	23	...	22	...	24	...	...	...	...	...	...	...	...	...
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23	...	...	26	25	...	...	...
20	25	...	...	...	...	...	...	...	28	...	...	...	...	25	...	28	...	...	...	...	...	...	...	...
25	...	...	...	...	...	28	...	...	...	...	...	...	...	...	...	...	27	...	29	...	...	...	...	...
Time.	TENSION OF THE WATER VAPOUR IN MM. AT TOUGGOURT.																							
7h.	6.6		6.3		7.1		7.4		8.0		7.9		6.1		6.7		6.4		6.7		8.3		8.1	
13h.	6.7		7.1		8.3		8.5		9.7		5.2		6.6		6.4		7.6		8.7		8.8		7.2	
18h.	5.7		6.7		8.0		8.9		7.9		4.6		6.3		6.7		7.8		8.7		8.0		6.0	

NOTE.—In this and other Tables a stands for a.m. and p for p.m.

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however, varies slightly according to the nature of the casting and the time taken in manufacture.

The "marble" glass filter, opaque to the visible spectrum, had a thickness of 7.3 mm. and transmitted over 80 per cent. for wave-lengths of 1.8μ to 2.2.μ, the transmission falling off to 6 per cent. for a wave-length of 0.8μ and to 2 per cent. for a wave-length of 3.4μ. With thicker plates of 1 cm. or more in thickness the infra-red was even better defined, but the percentage transmitted was diminished considerably.

The "yellow" filter which, as well as the blue, was contained in a cell of thickness 11 mm., was a solution 5.16 grams of potassium bichromate in 100 grams of water. It is very transparent between 0.7μ and 1.0μ and is nearly opaque at 1.4μ.

The "blue" filter, which consisted of a solution of 30 grams of copper sulphate in a similar quantity of water, transmitted small wave-lengths easily, but was nearly opaque to wave-lengths of 2.0μ or above.

The radiation of the partial and total intensities of solar radiation according to measurements made at Touggourt with light filters.

Dealing first with the infra-red filter it was found that 14 per cent. of the total radiation was transmitted at noon. This proportion—a fraction due not only to absorption but also to reflection at the surfaces of the glass—increased with the thickness of the atmosphere traversed and for zenith distances near 90° approached 30 per cent., or for what amounts to the same thing, for a thickness equal to about 25 atmospheres.

Detailed figures showing the diurnal variation and day to day changes in the percentages transmitted for April, 1924, are given in Table I. The table is abbreviated by taking the mean of definite intervals of *m* (the number of atmospheres traversed). The table shows a definite diurnal variation, but also that the changes from day to day were in general not considerable.

Turning now to the blue or copper sulphate filter Table II., formed in the same manner as in the previous case, gives details for the same month as Table I. and shows a diurnal variation equally well-marked, but in this case the *maximum* occurs at about noon and the *minimum* with large zenith distances.

The following figures compare briefly the two filters (*m* = number of atmospheres) :—

m	1	2	3	4	5	7·5	10	15	20
Blue, percentage transmitted	19	18	16	14	12	10	8	5	3
Red, ,, ,,	14	15	16	17	18	20	21	24	26

A more detailed analysis of Table II., however, leads to the conclusion that the maximum for the blue occurs before noon, a fact which may be seen on several days. In the case of the infra-red the minimum also occurred before mid-day.

Seeing that the variation of the infra-red is, and should be, the inverse of that of the "blue," one would expect that variations in the intermediate parts of the spectrum would be slight. That this is so is shown by the results obtained with the yellow filter given below.

m	1.4	2	3	5
	Percentage transmitted.			
March 25	40	—	43	44
April 12	—	42	—	—
April 13	39	41	42	44

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For the red Jena glass filter, which, as noted above, transmits from the yellow to the infra-red, there is again a well-marked increase with increasing zenith distances as shown by the following figures:—

m	1.2	1.5	2.0	3.5	5.0	7	15	22
Percentage transmitted	48	49	51	53	58	63	70	75

fuller details of which are given in Table III.

TABLE II.—FRACTIONS OF THE INTENSITY OF SOLAR RADIATION TRANSMITTED BY THE BLUE FILTER, TOUGGOURT, APRIL, 1924.

	April, 1924.							
	1.	2.	3.	4.	5.	13.	14.	15.
	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a.
Atmospheres.								
1.2	19 19	20 18	18 18	19 ...	19 19	21 21	21 ...	...
1.4	20 20	19 ...	19 ...	18 19	... ...	... 21	21 ...	19
1.6	19 ...	... ...	... 17	... ...	18 18	20 ...	... ...	19
1.8	... ...	... ...	... ...	17 ...	... ...	... 20	... ...	...
2.0	19 18	18 ...	18 16	16 ...	17 ...	19 ...	... 19	18
2.5	... ...	16 16	... 16	15 ...	... 16	17 17	18 ...	...
3.0	17 ...	... 15	16 15	14 ...	... ...	16 16	17 ...	...
3.5	... ...	14 ...	15 ...	... ...	... ...	15 ...	16 ...	...
4.0	15 15	13 15	14 14	... ...	14 ...	... ...	15 ...	...
4.5	... ...	... ...	... 13	... ...	... ...	... ...	... ...	...
5	14 13	11 ...	11 11	12 ...	... ...	... 13	13 12	...
6	13 ...	10 12	... ...	11 ...	10 ...	13 12	.. 11	...
7	12 12	9 ...	10 8	... ...	9 ...	... ...	... ...	...
8	... 11	... 9	... ...	8 ...	8 ...	... 11	10 9	...
9	... ...	... ...	9 7	... ...	... ...	... ...	... ...	...
10	... ...	... ...	8 ...	5 ...	7 ...	8 ...	9 ...	...
12	7 ...	... ...	... 5	... ...	... ...	... ...	... ...	...
14	6 ...	4 ...	... ...	... ...	... ...	... 7	6 4	...
16	... ...	... ...	... 1	... ...	... ...	... ...	... ...	...
18	5 ...	... ...	... ...	... ...	... ...	... ...	... ...	...
20	... ...	... ...	... ...	... ...	... ...	... 3	... ...	...
25	... ...	... ...	... ...	... ...	... ...	3 ...	... ...	...
30	4 ...	... ...	... ...	... ...	... ...	... ...	... ...	...

Table IV. (below) shows the diurnal variation in the total intensity of the solar radiation in gram calories per square centimetre per minute.

It is interesting to compare these latter results with those obtained at Warsaw and Bangkok. This comparison is given below, the figures again being gram calories per square centimetre per minute.

m	1.0	1.2	1.5	2.0	3.0	4.0	5.0	Vap. pressure mm.
Touggourt (April, 1924)	(1.41)	1.37	1.29	1.19	1.02	0.92	0.81	11
Warsaw (5 years) ...	(1.30)	1.26	1.18	1.07	0.91	0.80	0.70	7
Bangkok (May, 1923)	1.18	1.13	1.02	0.89	—	—	—	23

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TABLE III.—PERCENTAGES OF THE RED AS COMPARED WITH THE TOTAL INTENSITY OF SOLAR RADIATION AT TOUGGOURT, APRIL, 1924.

	1.	2.	3.	4.	5.	8.	9.	10.	11.	12.	13.	14.	15.
	a. p.	a. p.	a. p.	a. p.	a. p.	a p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.
Atmospheres.													
1.0	... ...	... ...	... ...	49 ...	... ...	... ...	... ...	... ...	... ...	47 ...	50 ...	... ...	... ...
	... ...	47 48	47 ...	48 49	49 49	49 ...	... ...	48 ...	48 ...	48 48	49 ...	... ...	... ...
1.2	... 49	48 ...	... ...	... ...	... ...	... ...	48 ...	... 49	49 49	... ...	... 51	... ...	51 ...
	... ...	... ...	... ...	... ...	... 50	49 ..	... ...	... ...	... ...	49 49	50 ...	50 ...	... ...
1.4	47 ...	... ...	... 48	... 50	... ...	... ...	49 ...	... ...	50 ...	... ...	... ...	... ...	52 ...
	... ...	... ...	48 ...	... 52	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
1.6	48 ...	49 ...	... ...	49 ...	50 ...	... ...	... 49	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	50 ...	... ...	... ...	... ...	... ...
1.8	49 ...	50 ...	49 ...	... ...	... ...	... ...	... ...	.. 50	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... 50	... ...	... ...	... ...	... ...	... ...	... 50	... ...	... ...	... ...	... ...
2.0	... ...	... ...	... ...	... ...	51 51	... ...	... ...	50 ...	51 ...	... 52	52 ...	... 54	53 ...
	... ...	51 ...	... ...	... ...	... ...	51 ...	... ...	... ...	... ...	50 ...	... ...	... ...	... ...
2.2	49 ...	... ...	.. ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... ...	... ...	... ...	.. ...	... 50	... ...	52 ...	... ...	... ...	... ...	... ...
2.6	... ...	... 52	... ...	... ...	52 ...	... ...	... ...	... 52	... ...	52 53	... ...	... ...	... ...
	50 ...	... ...	... 52	... ...	... 54	52 ...	... ...	... ...	... ...	... ...	... 54	... ...	... ...
3.0	... ...	53 ...	... ...	53 ...	... ...	... ...	... 51	... 53	53 53	... ...	53 ...	... ...	... ...
	... ...	... ...	53 ...	... ...	... ...	... ...	... ...	52 ...	.. ...	... 54	... ...	... ...	57 ...
3.4	52 54	... ...	... ...	... ...	... ...	... ...	52 ...	... 54	54 ...	... ...	56 56	... ...	... ...
	... ...	... ...	... 53	... ...	55 ...	54 ...	53 53	.. 55	... ...	54 ...	... ...	... ...	... ...
3.8	53 ...	... ...	... ...	... ...	... 56	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	54 54	54 ...	... ...	57 ...	... ...	54 55	54 ...	... 55	... ..	57 ...	56 ...	... ...
4.2	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	56 ...	... ...	... ...	... ...	... ...
	54 ...	... ...	56 56	... ...	... ...	... ...	55 ...	... ...	... ...	... ...	57 ...	... ...	... ...

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Bureau, R., and others.—*C.-R. Acad. sci.*, **178,** 1924, p. 556; 1623; **179,** 1924, p. 394; **180,** 1925, p. 529; 1122; *Onde, Elec.*, **4,** 1925, p. 31; 58.

This series of papers is best abstracted as a whole, it is concerned with the correlation between X disturbance and invasions of polar air.

The first paper states that from earlier directional data by others it is seen that X's always appear to come from regions over which a mass of fresh polar air is passing. X's from thunderstorm zones are a particular case of this.

Comparison of X disturbance and meteorological conditions shows X increasing when polar air passes over high mountains (Alps), *e.g.*:

November 7th, 1923. Cold front reached Alps in first half of night, followed by secondary rain cloud at 7 h., and a new cold front later in day. X's bad in France 1 h. to 3 h., fell off during day, and again increased at 18 h.

November 22, 1923. The worst day for X's in November and December, was most disturbed at 8 h. and again, more severely, between 18 h. and 20 h. These times correspond to arrival of, and complete establishment of, a cold current. X's disappeared somewhat suddenly in night of 22nd-23rd, when system became warmer and more humid.

Second paper asserts that the more marked relation thus traced in winter, as opposed to summer, is due to the need for vigorous reinforcement of winter fronts before they become troublesome, while summer fronts are sufficiently vigorous in themselves to give general disturbance without orographic reinforcement. At all seasons any increase in X disturbance is due to cold fronts. High potential energy of fresh polar air is degraded in all ways, kinetic (Cu. Nb. and squalls), electric (thunderstorms and X's), and by temperature equalization.

Instability is accentuated orographically by forced ascent, and reaches a maximum when the adiabatically cooled polar air crosses the summit and meets the air which has been warmed by the plain beyond. A phenomenon similar to this winter one is the warm season phenomenon in SW France, when cold fronts after crossing the Spanish plateaux and being reinforced by adiabatic cooling meet air warmed by contact with the Bay of Biscay and the ground.

Third paper cites, *e.g.*, May 14, 1924, cold front crossing Pyrenees slowly spreading over S.W. France, reaching Paris in beginning of night; followed by long thunderstorm period. On X side, some days of comparative quiet were followed by violent X's on evening of 13th at stations in W and SW France. At Paris maximum disturbance was from S on morning of 14th, followed by disturbance in all azimuths. This persisted, save for two short intervals, to end of month.

Cold front had produced X's before reaching France because reinforced by crossing Pyrenees, which favoured persistence of disturbance by energetic cooling at a height, while ground temperature is relatively high. Cold fronts arriving further north produces violent X's, but for a short time only, followed by calm.

Third paper sums up thus:—In our latitude at *all seasons*—

(1) X's invariably linked with cold fronts, even when these do not produce thunderstorms.
(2) They are put an end to by warm fronts.
(3) They are reinforced when cold front ascends mountainous country.
(4) They are also reinforced when cold front spreads over regions of high ground temperature.
(5) (3) and (4) together may give rise to persistence over long periods.

Fourth paper summarizes eleven months' observations, stated to confirm and amplify previous conclusions. The main additions are:—

(*a*) A statement of diurnal variation in May; X's start at noon, increase to 21 h., diminish, and reach secondary maximum at 4 h.

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(*b*) June and July phenomena of cold fronts with characteristic discontinuities of temperature and wind, but with no thunderstorms or showers. Neither do they produce X's so violent, numerous, or general as when front produces cloud or precipitation.

Range of reception of X's estimated, from examples cited, at 30 to 35 k.

Fifth paper classifies X's in two types:—

(1) Migratory, related to normal polar front, and characterized by alternate appearance and disappearance due to cold and warm fronts, absence of daily periodicity, azimuthal disymmetry, and temporal disymmetry. Latter thus: Before passage of front, short isolated discharges, increasing in frequency and intensity, changing to prolonged cracklings after front passes. If front passes as line squall, brief calm between pre-frontal and post-frontal types.

(2) Stagnant, related to pseudo polar fronts, characterized by appearance and disappearance linked with establishment and decay of disturbance current over France; no alternations of X's to correspond to alternations of centres of rise and fall of pressure; very distinct diurnal periodicity (appearance about 11 h., disappearance about 21 h.); almost simultaneous appearance and disappearance over all France, only directional effect being cum-solar swing; extreme and uninterrupted violence, rollings for hours on end; absence of azimuthal disymmetry.

Fifth paper thus sums up:—

In the different branches of the polar front, electro-magnetic energy only appears with invasions and (especially) expulsions of polar air. In pseudo fronts it is manifested violently at the same time at every point. The release is not brought about solely by discontinuities, origin and history of air masses have influence, polar air of cold fronts may have discharges unknown in equatorial air, while latter, between noon and night is the constant theatre of sudden ruptures of electro-magnetic equilibrium.

Sixth paper deals with observations on a transatlantic voyage of the "Jacques Cartier." Approach of cold front is preceded by appearance of X's 400 miles ahead at night, 250 miles by day, increasing till front passes, then frequently a lull for some hours. This temporary lull corresponds to appearance of sky, Cu. Nb. being replaced by St. Cu., but X's reappear in centre of pressure rise. Final disappearance is determined by a centre of fall or warm front.

Double fronts are accompanied by X's which are more severe the more pronounced the meteorological discontinuity.

These phenomena remain the same in low latitudes, X's there are in general governed by the disturbances of the polar front or their prolongations, the equatorial air of warm sectors even of very low latitude depressions has no X disturbance. Radical disappearance of X's was experienced in the south-east sector of a tropical cyclone (*cf.* Gherzi). On the other hand extensions of cold fronts or double fronts into the sub-equatorial regions produce a violent increase of X's felt hundreds of miles ahead of front.

"Atmospherics are the phenomenon that best gives evidence of the passing of meteorological disturbances in tropical regions; the other meteorological variables only indicate that passing in a much less regular way; moreover, they only give evidence of the meteorological disturbance when it has reached the observing station, while atmospherics announce it some hours in advance."

Gockel, A.—*Zeit. Hochfrequenztech.* 131 (May) 1925.

Herath's (*q.v.*) kite experiments show that when layers of low conductivity were over the observatory, X's were heard, thence he concluded that the boundary phenomena of these layers caused X's. Meissner goes further, and conjectures that these boundary phenomena at inversion strata or gliding surfaces are a gigantic source of generation of electricity. This was violently opposed at the Innsbruck conference (Autumn 1924). The author's experiments support Herath as to the coincidence between X disturbance and the approach of Föhn weather.

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Lugeon, J.—*Paris, C.-R. Acad. sci.*, **180**, 1925, p. 594.

Observations at Lausanne 1919 to 1922, at Zurich 1924.

X disturbance differs in plain, valley and mountain, correlation with the continental meteorological situation is difficult, but a direct relation with electrical conditions and weather in Alps and Jura appears. Every important change in disturbance appears to correspond to a change in vertical temperature gradient.

Equatorial air from the West, impinging on summits of 3,000–4000 m., carries beneath it a zone of great increase of X's, while high mountain stations record considerable diminution. When the surface of discontinuity reaches heights of Jura, crepitations and rollings are at a maximum on plateau and in valley. They then rapidly diminish, sometimes cease, but begin again feebly near the rain zone which is characterized by clicks. A little later the régime is uniform at all amplitudes.

The passage of cold fronts, lines of occlusion, or pseudo-fronts gives different and less distinct phenomena. On slow air-exchange rates, it has not been possible to determine whether any influence on X disturbance exists. The discharges are numerous, diverse, and strong on the average, diminishing in the precipitation zone. With a steeper cold-front gradient, disturbance precedes by 100 or 150 k. the ascent of cold masses in the Jura. X's increase rapidly from the moment this first barrier is passed, and rapidly invade the plateau, but remain weak at heights. They reach the heights an hour or two before the change of sign of the temperature gradient. The partial temperature inversion frequently characterizing this process is a sure sign of electrical instability. As soon as equilibrium is re-established X's diminish, the diminution beginning at the lower levels.

Directional observations showed direction of X disturbance in closed valleys to coincide with the discluding sense of the valley before a temperature fall, and with its ascending sense in Föhn weather or temperature rise.

A station 2,000 m. above a valley station recording many X's showed practically no X's till itself immersed in cloud masses condensed by the deepening stream of cold air. In winter anti-cyclones, with strong temperature inversions, the plateau is covered by the high mists of strato cumulus. This seems to screen the plateau from distant X's recorded at heights.

Preliminary conclusions are stated thus:—

(1) Intensity frequency nature and direction of X's vary with altitude.

(2) This variation is closely connected with variations of vertical temperature gradient. Cooling augments, heating diminishes the phenomenon.

(3) Lower layers are much more disturbed than higher.

(4) Apart from X's of proved distant origin, range of X's originating in the lower layers does not seem to exceed 250 k., and remains almost always under 150 k. in mountainous regions.

Watson Watt, R. A.—*London, Proc. Phys. Soc.*, **37**, 1925, p. 230; *London, J.R. Aero. Soc.*, **29**, 1925, p. 170.

Shows correlation between apparent sources of atmospherics and their meteorological environment. Of 490 cases examined, 25 per cent. fell within 250 k. of reported thunder, a further 28 per cent. were associated with more distant thunderstorms or with squall phenomena, 21 per cent. more with rain, 13 per cent. more fell on barometric minima, leaving 13 per cent. uncorrelated.

Reports the tracking of a cold front for 2,700 k. by automatic recorders of X's.

The compiler of the bibliography desires to acknowledge his indebtedness to the Radio Research Board for giving facilities for the work, and to Miss D. E. Harvey, B.Sc., translator and abstractor to the Board, whose admirable abstracts of current radiotelegraphic literature have lightened his task.

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TABLE I.—Summary of Conclusions by Different Observers as to Meteorological Relations of Atmospherics.

Observer. In approximate order of publication.	Approx. Date of Observations	Place.	Pressure.	Temperature	Increase of Temperature.	Relative Humidity.	Absolute Humidity.	Rainless Cloud.	Cloud.	Rain.	Fog.	Visibility.	Dust.	Wind Direction	Wind Velocity.	Air Turbulence.	Convection.	Thunderstorms	Potential Gradient.	Increase of Pot. Gradient.	Terrestrial Magnetism.	Magnetic Storms	Aurora.	Depressions.
Jackson	1902	Mediterranean	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	+	...	...	...	...	...	+
Schwartzhaupt	1910	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Loring	1911	Great Britain	...	...	...	...	...	...	...	+	...	...	...	Inshore	...	...	...	...	...	...	...	...	...	...
Esau	1908-11	Germany	...	...	...	−	...	−	+	...	−	+	−	...	+	...	...	...	...	...	...	...	...	...
Erskine Murray	1911	Gt. Britain, etc.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Taylor	1911	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	−	...	...	...
Round	1912	do. and Atlantic	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...
Delval	1912	France	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Mosler	1911-12	Germany	...	...	...	...	...	−	+	−	−	...	...	...	...	...	...	+	+	+	...	...	...	...
Lutze	1913	Germany	...	...	...	...	...	Uniform Sheet + Inside	...	...	...	...	...	·	...	...	...	...	δ	...	...	...	...	...
Duroquier	1913	France	...	...	−	...	...	...	...	...	...	...	...	δ	...	...	+	+	...	...	...	...	...	...
Marriott	1914	U.S.A.	...	...	+	...	...	...	...	...	...	...	...	δ	...	...	...	...	...	...	...	...	...	...
Curtis	1914	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
B.A.Commission	1915	Gt. Britain, etc.	δ	...	...	...	...	...	...	+	...	...	...	Inshore	...	...	+	+	...	...	...	...	O	...
De Groot	1917	Dutch E. Indies	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	+	...	...	...
Eccles	1912-19		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Culver	1919	U.S.A.	O	−	...	+	O	O	...	...	...	...	...	O	−	...	...	+	—	+	+	...	...	...
Telegraphen Tech. Vers.	1920	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	O	+	O Save Ts	...	...	...	...	...
Brooks & Lyman	1920	U.S.A.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	O	...
Goldschmidt	1915-17	Belgian Congo	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Rothé	1921	France	...	...	...	...	...	+	+	−	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Wiedenhilf	1921	Germany	−	+	...	−	+	−	...	+	...	...	...	...	−	...	+	...	−	+	...	...	...	...
Lacoste	1921	Alsace	...	...	...	...	...	...	...	...	+	...	...	...	...	...	+	+	...	...	...	...	...	+
Bouthillon	1921		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...
Wolf	1922	Germany	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	Hum	In + Summer
Crawley	1908	Mediterranean	−	+	...	−	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Marchand	1921	U.S.A.	...	...	...	...	...	...	...	...	...	...	...	...	−	...	...	+	...	...	...	...	...	...
Watson Watt	1916-18	Great Britain	...	...	...	...	...	...	...	+	...	...	...	...	...	...	+	+	...	...	...	...	...	+
Stoye	1915-17	Germany	...	...	...	...	..	+	...	...	+	...	...	...	...	...	+	+	...	...	...	...	...	...
		Relation to change of element δ	1	−	−	−	−	−	−	−	−	−	−	2	−	−	−	−	1	−	−	−	−	−
		No relation O	1	−	−	−	1	1	−	−	−	−	−	1	−	−	1	−	1	−	−	−	2	−
		Direct relation +	−	2	1	1	1	3	3	6	2	1	−	−	1	1	8	19	1	3	2	−	1	4
		Inverse relation −	2	1	1	3	−	3	−	2	2	−	1	−	3	−	−	−	2	−	−	1	−	−

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Light Filter Measurements made by the Polish Solar Radiation Expedition to Siam in 1923, and at Touggourt in the Sahara Desert 1924.—Dr. Ladislas Gorczynski.

Introduction.

The Council are indebted to Dr. Ladislas Gorczynski, the Director of the Meteorological Service of Poland, for permission to print the following abstract from an important paper[1] giving an account of the observations of solar radiation made with light filters by a Polish Expedition, headed by Dr. Gorczynski on a voyage from Europe to Siam through the Red Sea and Indian Ocean in 1923, and at Touggourt in the Sahara Desert in 1924.

The measurements in 1923 were chiefly made with bimetallic actinometers, over 40,000 observations being made in the period March to August, either on board ship or on the plains and mountains of the equatorial region. For the observations at Touggourt a self-registering instrument was also employed, in which a Moll thermophile[2] was automatically directed towards the sun, the thermo-electric currents thus induced being recorded by self-registering milli-voltmeters of suitable form.[3] Eighty couples of manganin-constantin were employed, which, with an intensity of radiation of one gram calory per square centimetre per minute, gave an E.M.F. of about 20 milli-volts. A spectro-heliograph was also constructed in which the sun's rays, after passing through a prism of special flint glass, rock salt or fluorite, reached a linear thermopile, the thermo-electric currents being recorded by means of a mirror galvanometer and a photographic registering apparatus. The prism was rotated slowly by means of clockwork mechanism, the solar spectrum thus passing in front of the slit of the thermopile in about ten minutes. A portable form was constructed later (in 1925).

Approximate results as to the changes in intensity in the different parts of the spectrum were at first obtained by means of light filters used in conjunction with actinometers, both during the voyage to Siam and at Touggourt.

The filters employed were four in number:—

1. Red Jena glass (F.4.512), which transmits from the yellow well into the infra-red.
2. "Marble" glass, opaque to visible rays, used for the infra-red part of the spectrum.
3. A yellow—a solution of potassium bichromate.
4. Blue—a solution of copper sulphate.

The red filter was 3.95 mm. thick and transmitted more than 80 per cent. of the total intensity between wave-lengths of 0.8μ and 2.5μ. It showed a rapid diminution towards the yellow, being opaque for wave-lengths of 0.54μ or less. In the infra-red the transmission fell off from 55 per cent. at 2.8μ to zero at 4.4μ. The coefficient of transmission,

[1] For a more detailed account of some of these observations reference may be made to a paper by the same author, "Memoirs de l'intensité totale et partielle du Rayonnement solaire effectuées en 1924 en Afrique Nord," *Annales du Service Botanique de Tunisse*, May, 1926, pp. 1-59.

[2] First demonstrated at a Congress at Delft in 1913. See also Moll, W. J. H., "A thermopile for Measuring Radiation," *Proc. Phys. Soc. London*, **35**, part 5, p. 257.

[3] See Gorczynski, Lad., "On a Simple Method of Recording the Total and Partial Intensities of Solar Radiation," *Washington, Monthly Weather Review*, 1924, June.

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TABLE I.—Percentage of the Infra-red as Compared with the Total Intensity of Solar Radiation at Touggourt, April, 1924.

	April, 1924.																											
	1.		2.		3.		4.		5.		8.		9.		10.		11.		12.		13.		14.	
	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.	a.	p.
Atmospheres.	%		%		%		%		%		%		%		%		%		%		%		%		%		%	
1.2	14	14	14	...	14	...	14	...	15	...	...	...	13	...	14	15	14	...	14	...	14	14	15	...				
1.4	...	...	...	...	...	14	...	15	14	15	15	...	...	14	...	...	...	14	15	...	...	...	15	...				
1.6	...	...	14	...	...	...	...	...	...	...	...	...	14	...	...	...	...	...	...	15	...	...	...	...				
1.8	...	16	...	...	...	15	...	...	15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16				
2.0	15	...	15	...	15	...	15	...	...	...	...	...	...	...	15	...	15	15	15	...	15	15	...	...				
2.5	...	...	...	16	...	...	...	...	16	..	...	...	...	...	. .	...	...	...	...	...	...	16	...	...				
3.0	...	...	...	...	...	16	...	...	...	...	16	...	...	..	...	16	16	...	...	16	...	...	...	17				
3.5	...	17	16	...	...	...	...	...	...	18	...	...	16	...	...	...	...	...	17	...	16	...	16	...				
4.0	...	...	...	...	...	...	...	...	17	...	...	...	...	...	16	17	...	...	...	...	...	...	...	...				
4.5	...	...	17	...	...	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
5	...	...	18	17	17	...	...	...	...	...	...	...	...	17	...	...	17	17	18	...	17	...	...	...				
6	17	...	...	...	...	...	19	...	...	...	18	...	17	...	...	...	18	...	...	...	...	...	...	19				
7	18	...	19	...	...	...	21	...	...	...	...	...	...	...	20	...	. .	19	...	...	...	...	...	...				
8	...	20	...	...	20	20	...	...	21	...	19	...	19	...	...	20	...	...	20	...	...	20	19	...				
9	19	...	...	...	...	...	22	...	...	...	...	...	...	...	...	...	...	20	...	...	22	...	...	...				
10	...	...	22	...	...	...	...	...	22	...	...	...	20	...	21	...	21	...	...	...	...	...	...	...				
12	20	...	...	...	...	22	23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
14	...	...	...	...	...	...	...	...	24	...	...	...	...	...	...	22	...	...	22	...	23	...	...	24				
16	...	...	...	...	...	...	...	...	...	...	23	...	22	...	24	...	...	...	...	...	...	...	...	...				
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23	...	...	26	25	...	...	...				
20	25	...	...	...	...	...	...	...	28	...	...	...	...	25	...	28	...	...	...	...	...	...	...	...				
25	...	...	...	...	...	28	...	...	...	...	...	...	...	...	...	...	27	...	29	...	...	...	...	...				
Time.	Tension of the Water Vapour in mm. at Touggourt.																											
7h.	6.6		6.3		7.1		7.4		8.0		7.9		6.1		6.7		6.4		6.7		8.3		8.1					
13h.	6.7		7.1		8.3		8.5		9.7		5.2		6.6		6.4		7.6		8.7		8.8		7.2					
18h.	5.7		6.7		8.0		8.9		7.9		4.6		6.3		6.7		7.8		8.7		8.0		6.0					

Note.—In this and other Tables a stands for a.m. and p for p.m.

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however, varies slightly according to the nature of the casting and the time taken in manufacture.

The "marble" glass filter, opaque to the visible spectrum, had a thickness of 7.3 mm. and transmitted over 80 per cent. for wave-lengths of 1.8μ to 2.2.μ, the transmission falling off to 6 per cent. for a wave-length of 0.8μ and to 2 per cent. for a wave-length of 3.4μ. With thicker plates of 1 cm. or more in thickness the infra-red was even better defined, but the percentage transmitted was diminished considerably.

The "yellow" filter which, as well as the blue, was contained in a cell of thickness 11 mm., was a solution 5.16 grams of potassium bichromate in 100 grams of water. It is very transparent between 0.7μ and 1.0μ and is nearly opaque at 1.4μ.

The "blue" filter, which consisted of a solution of 30 grams of copper sulphate in a similar quantity of water, transmitted small wave-lengths easily, but was nearly opaque to wave-lengths of 2.0μ or above.

The radiation of the partial and total intensities of solar radiation according to measurements made at Touggourt with light filters.

Dealing first with the infra-red filter it was found that 14 per cent. of the total radiation was transmitted at noon. This proportion—a fraction due not only to absorption but also to reflection at the surfaces of the glass—increased with the thickness of the atmosphere traversed and for zenith distances near 90° approached 30 per cent., or for what amounts to the same thing, for a thickness equal to about 25 atmospheres.

Detailed figures showing the diurnal variation and day to day changes in the percentages transmitted for April, 1924, are given in Table I. The table is abbreviated by taking the mean of definite intervals of *m* (the number of atmospheres traversed). The table shows a definite diurnal variation, but also that the changes from day to day were in general not considerable.

Turning now to the blue or copper sulphate filter Table II., formed in the same manner as in the previous case, gives details for the same month as Table I. and shows a diurnal variation equally well-marked, but in this case the *maximum* occurs at about noon and the *minimum* with large zenith distances.

The following figures compare briefly the two filters (*m* = number of atmospheres):—

m	1	2	3	4	5	7·5	10	15	20
Blue, percentage transmitted	19	18	16	14	12	10	8	5	3
Red, ,, ,,	14	15	16	17	18	20	21	24	26

A more detailed analysis of Table II., however, leads to the conclusion that the maximum for the blue occurs before noon, a fact which may be seen on several days. In the case of the infra-red the minimum also occurred before mid-day.

Seeing that the variation of the infra-red is, and should be, the inverse of that of the "blue," one would expect that variations in the intermediate parts of the spectrum would be slight. That this is so is shown by the results obtained with the yellow filter given below.

m	1.4	2	3	5
	Percentage transmitted.			
March 25	40	—	43	44
April 12	—	42	—	—
April 13	39	41	42	44

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For the red Jena glass filter, which, as noted above, transmits from the yellow to the infra-red, there is again a well-marked increase with increasing zenith distances as shown by the following figures:—

m	1.2	1.5	2.0	3.5	5.0	7	15	22
Percentage transmitted	48	49	51	53	58	63	70	75

fuller details of which are given in Table III.

TABLE II.—Fractions of the Intensity of Solar Radiation Transmitted by the Blue Filter, Touggourt, April, 1924.

	April, 1924.							
	1.	2.	3.	4.	5.	13.	14.	15.
	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a.
Atmospheres.								
1.2	19 19	20 18	18 18	19 ...	19 19	21 21	21 ...	...
1.4	20 20	19 ...	19 ...	18 19	... ...	... 21	21 ...	19
1.6	19 ...	... ...	... 17	... ...	18 18	20 ...	... ...	19
1.8	... ...	... ...	... ...	17 ...	... ...	... 20	... ...	...
2.0	19 18	18 ...	18 16	16 ...	17 ...	19 ...	... 19	18
2.5	... ...	16 16	... 16	15 ...	... 16	17 17	18 ...	...
3.0	17 ...	... 15	16 15	14 ...	... ...	16 16	17 ...	...
3.5	... ...	14 ...	15 ...	... ...	... ...	15 ...	16 ...	...
4.0	15 15	13 15	14 14	... ...	14 ...	... ...	15 ...	...
4.5	... ...	... ...	... 13	... ...	... ...	... ...	... ...	...
5	14 13	11 ...	11 11	12 ...	... ...	... 13	13 12	...
6	13 ...	10 12	... ...	11 ...	10 ...	13 12	... 11	...
7	12 12	9 ...	10 8	... ...	9 ...	... ...	... ...	...
8	... 11	... 9	... ...	8 ...	8 ...	... 11	10 9	...
9	... ...	... ...	9 7	... ...	... ...	... ...	... ...	...
10	... ...	... ...	8 ...	5 ...	7 ...	8 ...	9 ...	...
12	7 ...	... ...	... 5	... ...	... ...	... ...	... ...	...
14	6 ...	4 ...	... ...	... ...	... ...	... 7	6 4	...
16	... ...	... ...	... 1	... ...	... ...	... ...	... ...	...
18	5 ...	... ...	... ...	... ...	... ...	... ...	... ...	...
20	... ...	... ...	... ...	... ...	... ...	... 3	... ...	...
25	... ...	... ...	... ...	... ...	... ...	3 ...	... ...	...
30	4 ...	... ...	... ...	... ...	... ...	... ...	... ...	...

Table IV. (below) shows the diurnal variation in the total intensity of the solar radiation in gram calories per square centimetre per minute.

It is interesting to compare these latter results with those obtained at Warsaw and Bangkok. This comparison is given below, the figures again being gram calories per square centimetre per minute.

m	1.0	1.2	1.5	2.0	3.0	4.0	5.0	Vap. pressure mm.
Touggourt								
(April, 1924)	(1.41)	1.37	1.29	1.19	1.02	0.92	0.81	11
Warsaw								
(5 years) ...	(1.30)	1.26	1.18	1.07	0.91	0.80	0.70	7
Bangkok								
(May, 1923)	1.18	1.13	1.02	0.89	—	—	—	23

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TABLE III.—PERCENTAGES OF THE RED AS COMPARED WITH THE TOTAL INTENSITY OF SOLAR RADIATION AT TOUGGOURT, APRIL, 1924.

	1.	2.	3.	4.	5.	8.	9.	10.	11.	12.	13.	14.	15.
	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.	a. p.
Atmospheres.													
1.0	... ...	... ...	... ...	49 ...	... ...	... ...	... ...	... ...	... ...	47 ...	50 ...	... ...	... ...
	... ...	47 48	47 ...	48 49	49 49	49 ...	... ...	48 ...	48 ...	48 48	49 ...	... ...	... ...
1.2	... 49	48 ...	... ...	... ...	... ...	... ...	48 ...	... 49	49 49	... ...	... 51	... ...	51 ...
	... ...	... ...	... ...	... ...	... 50	49 ..	... ...	... ...	... ...	49 49	50 ...	50 ...	... ...
1.4	47 ...	... ...	... 48	... 50	... ...	... ...	49 ...	... ...	50 ...	... ...	... ...	... ...	52 ...
	... ...	... ...	48 ...	... 52	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
1.6	48 ...	49 ...	... ...	49 ...	50 ...	... ...	... 49	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	50 ...	... ...	... ...	... ...	... ...
1.8	49 ...	50 ...	49 ...	... ...	... ...	... ...	... ...	.. 50	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... 50	... ...	... ...	... ...	... ...	... ...	... 50	... ...	... ...	... ...	... ...
2.0	... ...	... ...	... ...	... ...	51 51	... ...	... ...	50 ...	51 ...	... 52	52 ...	... 54	53 ...
	... ...	51 ...	... ...	... ...	... ...	51 ...	... ...	... ...	... ...	50 ...	... ...	... ...	... ...
2.2	49 ...	... ...	.. ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	... ...	... ...	... ...	... ...	.. ...	... 50	... ...	52 ...	... ...	... ...	... ...	... ...
2.6	... ...	... 52	... ...	... ...	52 ...	... ...	... ...	... 52	... ...	52 53	... ...	... ...	... ...
	50 ...	... ...	... 52	... ...	... 54	52 ...	... ...	... ...	... ...	... ...	... 54	... ...	... ...
3.0	... ...	53 ...	... ...	53 ...	... ...	... ...	... 51	... 53	53 53	... ...	53 ...	... ...	... ...
	... ...	... ...	53 ...	... ...	... ...	... ...	... ...	52 ...	.. ...	... 54	... ...	... ...	57 ...
3.4	52 54	... ...	... ...	... ...	... ...	... ...	52 ...	... 54	54 ...	... ...	56 56	... ...	... ...
	... ...	... ...	... 53	... ...	55 ...	54 ...	53 53	.. 55	... ...	54 ...	... ...	... ...	... ...
3.8	53 ...	... ...	... ...	... ...	... 56	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...
	... ...	54 54	54 ...	... ...	57 ...	... ...	54 55	54 ...	... 55	... ..	57 ...	56 ...	... ...
4.2	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	56 ...	... ...	... ...	... ...	... ...
	54 ...	... ...	56 56	... ...	... ...	... ...	55 ...	... ...	... ...	... ...	57 ...	... ...	... ...

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TABLE IV.—Values of Total Intensity of Solar Radiation, gr. cal., cm^{-2}, min.$^{-1}$ during Spring, 1924, from Measurements made with Bimetallic Actinometers.

	1.2.	1.5.	2.0.	2.5.	3.0.	3.5.	4.0.	4.5.	5.0.
Date. m.									
March 22 a.	...	...	...	...	...	...	.93	.90	.87
,, 23 a.	1.40	1.29	1.18	...	...	...	...	...	...
p.	1.41	...	...	...	...	...	...	...	...
,, 24 a.	...	1.34	...	...	...	...	...	...	...
,, 25 a.	1.38	1.30	...	1.11	...	...	...	...	...
p.	...	1.31	1.20	1.11	1.07	1.05	...	...	.78
,, 26 a.	1.39	1.23	...	...	.99	.91	.89	...	...
,, 27 a.	1.41	...	1.07	...	...	...	...	...	...
p.	1.42	1.35	...	...	...	...	...	...	...
,, 28 a.	...	1.27	1.17	...	...	...	...	...	...
,, 30 a.	1.37	1.32	1.22	1.14	1.04	.94	.92	.86	.82
p.	1.37	...	...	...	...	.92	...	...	...
,, 31 a.	1.41	1.21	...	...	...	...	...	...	...
April 1 a.	1.36	1.34	1.20	1.08	.93	...	.90	.83	.80
,, 2 a.	1.44	1.34	1.21	1.12	1.03	...	.93	...	...
,, 3. a.	1.33	1.23	...	...	...	...	...	...	...
p.	1.33	...	1.20	1.09	1.02	.95	...	.85	...
,, 4 a.	1.34	1.18	1.09	1.00	.92	...	...	...	...
p.	1.34	1.24	...	...	...	...	...	...	...
,, 5 a.	1.36	1.29	1.18	...	1.00	.94	.87	...	...
p.	...	1.29	...	1.09	.93	...	...	...	...
,, 8 a.	1.35	1.22	1.15	1.10	1.00	...	.90	...	...
,, 9 a.	1.27	1.25	1.17	...	1.09	...	.96	.91	...
p.	1.34	1.27	1.21	...	1.08	...	.94	.90	...
,, 10 a.	1.32	1.29	1.20	...	...	.91	...	...	...
p.	1.29	1.28	...	...	...	.94	...	...	...
,, 11 a.	1.34	1.28	1.23	1.11	1.06	.99	.90	.83	.78
p.	1.39	1.25	1.22	...	1.07	1.01	.95	...	.84
,, 12 a.	1.35	1.27	1.16	1.07	...	.87	.83	...	...
p.	1.33	1.28	...	...	.97	...	...	...	...
,, 13 a.	1.32	1.27	1.13	...	.94	...	...	...	...
p.	1.34	...	...	...	...	...	...	...	...
,, 14 a.	...	1.26	...	1.07	1.00	.93	.86	.78	.71
Mean values...	1.36	1.28	1.18	1.09	1.01	.95	.91	.86	.80
Number of measurements	27	27	18	12	17	12	13	8	8

The decrease in the intensity of the red and infra-red parts of the spectrum from Europe towards the Equator.

For these measurements two bimetallic actinometers provided with filters were used on the voyage to and from Siam and Java, comparisons being made both before and after the voyage and also at the Meteorological Observatory, Batavia, in June, 1923—the latter with a silver disc pyrheliometer.

The filter used was of red Jena glass, thickness 3.95 mm., which is very nearly opaque to green rays, but transparent for the red and infra-red.

The observations are summarised in Table V.

The decrease, which is easily apparent, is due chiefly, no doubt, to an increase in humidity towards the equator, but is due also in part to the increasing altitude of sun. Allowing, however, for the changes in the sun's altitude there still remains a decrease of about six per cent.

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TABLE V.—Progressive Decrease of the Partial Intensity in the "Red Part" of the Solar Radiation in Relation to the Total Intensity.

Date. 1923.	Zenith distance.	Atmosphere thickness.	Air temp. Cent. noon.	Max. gr. cal. cm.$^{-2}$ min.$^{-1}$ 11 h. to 13 h.	Percentage of the intensity in the "red part." Observed minimum.	Remarks. Ship's position.
A. Actinometric measurements on board M.S. "Jutlandia."						
March 8	43	1.38	16	1.37	52	Atlantic Ocean, 38° N., 10° W.
„ 13	39	1.28	15	1.33	51	Mediterranean Sea, 36° N., 5° E.
„ 18	30	1.15	21	1.20	49	Suez Canal, 29° N., 33° E.
„ 20	22	1.09	28	1.22	48	Red Sea, 22° N., 38° E.
„ 23	12	1.03	27	1.34	46	Gulf of Aden, 12° N., 44° E.
„ 28	9	1.01	31	1.36	45	Indian Ocean, 10° N., 65° E.
April 14	6	1.01	29	1.28	45	Gulf of Siam, Pacific, 3° N., 101° E.
B. Actinometric measurements in Siam.						
May 5	2	1.00	32	1.15	44	City of Bangkok, Latitude 13° 44′ N., Longitude 100° 30′ E., Height 10 m.
„ 10	4	1.01	32	1.10	44	
„ 15	5	1.01	33	1.20	44	
„ 21	6	1.01	33	1.21	44	
C. Mount Pangerango, Java. Height, 3,023 metres. 6° 45′ S., 106° 58′ E.						
June 15	30	0.81	16	1.6	—	Actinometric measurements made during the morning-hours only; the values, reduced to noon, have only a provisional character.
„ 16	30	0.81	11	1.6	—	
„ 17	30	0.81	13	1.6	—	
D. On board M.S. "Falstria."						
July 22	16	1.04	29	1.21	45	Indian Ocean, 4° N., 61° E.
„ 28	8	1.02	31	1.11	45	Gulf of Aden, 11° N., 47° E.
„ 31	0	1.00	32	1.17	45	Red Sea, 18° N., 40° E.
Aug. 1	4	1.01	32	1.16	47	Red Sea, 22° N., 38° E.
„ 5	15	1.04	27	1.25	47	Mediterranean Sea, 32° N., 32° E.
„ 9	22	1.08	28	1.25	48	Mediterranean Sea, 38° N., 16° E.
E. Continent of Europe.						
Aug. 13	29	1.14	34	1.30	50	Montpellier 43° 6′ N., Agric. Met. St.
„ 21	37	1.23	29	1.17	51	Paris 48° 8′ N., Observ. Parc. St. Maur.
Sept. 17	50	1.54	22	1.17	54	Warsaw 52° 2′ N., 21° 0′ E.
Oct. 3	56	1.78	15	0.72	60	Polish Meteorological Institute.

It is probable, however, that this decrease is compensated partly by an increase in the ultra-violet, but the energy in this part of the spectrum amounts to only about one per cent. of the total radiation and for the decrease to be fully compensated in this manner the effect of the ultra-violet rays would have to be several times larger in equatorial than in

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middle European latitudes. Further research is, however, necessary before the question can be completely solved. The study of these conditions over only a narrow belt of the globe is insufficient and other expeditions should be undertaken to oceanic islands, equatorial mountains, desert regions and generally to suitable places in all the characteristic regions of the world.

Abstract.

OBITUARY.

Mr. W. S. Clark, J.P.

The death occurred at Millfield, Street, Somerset, on November 20, 1925, of Mr. W. S. Clark, aged eighty-six.

Mr. Clark, who was educated at the Friends' Schools at Sidcot and York, was at the time of his death the senior rainfall observer reporting to the British Rainfall Organization. He began his measurements in 1857 at the age of nineteen. His observations appeared regularly in *English Rainfall* and its successor, *British Rainfall,* since 1860, and, apart from two moves, once to the next house in the centre of the village in 1866 and next to his last residence three-quarters of a mile away, the observations form a homogeneous series.

He was a J.P. for the County of Somerset and one of the original County Aldermen, while he promoted the establishment of technical and secondary and day continuation schools in Street as well as endowing a scheme of bursaries for the elementary schools.

He was elected a Fellow of this Society in 1905.

Mr. A. Clay, J.P.

The death of Mr. A. Clay occurred on December 22, 1925, at his residence, Darley Hall, Matlock, in his eighty-fourth year, after only a few days' illness.

A man of wide interests, he was held in high regard by all who knew him.

He made several world tours in his early life and showed a great interest in meteorology both at home and abroad. He began rainfall measurements as early as 1858, and these were continued at Darley Hall on his removal there in 1887.

He was elected a member of this Society in 1907.

Mr. Hedley H. R. Chapman.

We regret to hear of the death of Mr. Hedley H. R. Chapman, which occurred at Broadstairs in January.

He was elected a Life Fellow of this Society in 1907.

Rev. J. C. Fox.

We regret to announce the death at Combe, Parkstone, on March 5, 1926, of the Rev. James Charles Fox, in his seventy-first year.

He was a regular rainfall observer from the time he became Rector of Templecombe, Somerset, in 1891 until 1921, when he resigned the

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living owing to failing health. He retired to Parkstone, Dorset, where he continued observations until last October.

He was elected a Fellow of this Society in 1907.

Prof. John Gray McKendrick, M.D., F.R.S.

We regret to announce the death, on January 2, of Prof. John Gray McKendrick, F.R.S., Emeritus Professor of Physiology in the University of Glasgow.

Educated in Aberdeen, where he took his degree of M.D., his original intention was to engage in general practice, but was induced later to accept the position of assistant to Dr. H. Bennett, then Professor of Physiology at Glasgow. He soon gained a great reputation as a teacher. He succeeded Prof. Buchanan to the Chair of Physiology in 1876, retiring in 1906 after thirty years.

He was a Fellow of the Royal Societies of London and Edinburgh, and during the active period of his life was examiner in physiology to many of the British Universities. His publications include *Outlines of Physiology* (1878), a *Text-book of Physiology* (1888-9), a *Life of Helmholtz* (1899), and the *Boyle Lecture on Hearing* (1899), all of which were characterized by a high literary quality.

He took a great interest in meteorology and was elected a Fellow of the Scottish Meteorological Society in 1866.

Mr. R. E. Middleton, M.I.C.E., M.I.M.E.

We regret to announce the death of Mr. R. E. Middleton, M.I.C.E., etc., the son of the late Rev. Joseph Empson Middleton, Vice-Principal of St. Bees College.

Born in 1844, Mr. Middleton was educated at St. Bees Grammar School and Charterhouse. On completing his education he was apprenticed to engineering at Newcastle, and in 1863 spent many months at sea. Returning home, he held in succession various engineering positions, and after a spell of duty in Spanish Honduras, turned his attention to the problems of sewerage and water supply. He gave lengthy expert evidence before the Royal Commission on London Water Supply in 1898-99, and also before many committees of the Houses of Parliament.

He was the author of several pamphlets on water supply, and with Mr. O. Chadwick was part author of a "Treatise on Surveying."

He was elected a Fellow of this Society in 1894 and served on the Council in 1911.

REVIEWS.

Die Beobachtungensmethoden des modernen Meteorologen. By Dr. M. Robitzsch. Sammlung Geophysikalischer Schriften, No. 4. Berlin (Gebrüder Borntraeger), 1925. 8vo. Pp. 125, 25 figures in the text. Gold Mark 6.75.

This little book, which forms one of a series of geophysical memoirs, is not, as its name might suggest, a handbook for the guidance of the meteorological observer, although the intelligent observer would find in it a store of useful information to stimulate his interest in the subject and elevate him above the mere monotony of observational routine. Dr. Robitzsch aims, rather, at presenting a short treatise on observational methods primarily for the use of the meteorologist at headquarters who

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is given an insight into the physical significance of the individual observations and the respective parts which they play in building up our knowledge of the structure of the atmosphere.

The book is divided into seven chapters, each of which deals with a distinct group of observations. More than half the book is taken up by the first three chapters, in which the author devotes himself to a discussion of the fundamental observations of pressure, temperature and humidity. Such matters as the correction and reduction of barometer readings, the temperature coefficient of an aneroid barometer and the theories of the bi-metallic thermograph and the hair hygrometer receive very full treatment.

The next three chapters deal with wind structure and measurement; radiation, including sunshine recording and cloud observations; precipitation, with which is included atmospheric electricity. The last chapter is devoted to upper air observations, prominence being given to the meteorograph and the interpretation of the records from it.

The book is admirably conceived and is written in a clear and convincing style. The diagrams, though few in number, are good. Any student of meteorology should read the book with profit.

F. E.

Traité d'électricité atmosphérique et tellurique. Publié sous la direction de E. MATHIAS par J. BOSLER, Dr. P. LOISEL, Prof. R. DONGIER, Prof. Ch. MAURAIN, G. GIROUSSE, Prof. R. MESNY. (Comité Française de Géodésie et de Géophysique: Publication de la 6e Section.) Paris (Les Presses universitaires de France), 1924. Pp. xx + 580. 40 francs.

Until recently, students of atmospheric electricity who did not read German easily, when seeking guidance to the solution of their problems, have been compelled to labour over the grammatical difficulties of textbooks in German, as no others were in existence. Hence, to most English workers the above treatise in French should make an immediate appeal purely on linguistic grounds, but acquaintance with its wide scope and soundness makes the appeal twofold.

The publication has been issued by the French Committee for Geodesy and Geophysics, the national counterpart of the international committee of that name. Mons. Mathias, secretary of the 6th section of this committee, which is responsible for terrestrial magnetism and atmospheric electricity, initiated and supervised the whole production. As explained in the preface by the president of the section, Mons. Berthelot, the work was intended to be so comprehensive that colossal experience and untiring industry would have been required of a single author, who must of necessity have taken a long time to complete his writing. Thus, to expedite publication and keep the work reasonably up to date, the authorship was distributed among seven eminent French geophysicists, specialists in their own branches of the science.

The volume is divided into three sections. Section I. deals with the so-called invisible phenomena displayed in the lower layers of the atmosphere. Here, Mons. Dongier gives full descriptions of the various instruments used for measuring potential gradient, with many valuable practical details adopted for continuous registration and standardisation of the records. In this connection one notes that Mons. Chauveau deplores the increasing preference for the quasi-continuous record of the Benndorf instead of the detailed photographic record of the Kelvin water-dropper electrograph. The preference can only be upheld on grounds of economy and expediency. Prof. Maurain gives lucid descriptions of the methods of measurement employed, and the theoretical considerations involved, in the study of electrical dissipation, conductivity, ionization and conduction currents in the atmosphere. Numerous numerical examples

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are also included. Without encroaching on Prof. Maurain's domain, Prof. Mathias describes the well-known laboratory methods of determining the mobilities of small and large ions. Collected summaries of the mean values of the above electrical quantities for different parts of the world, both on land and sea, form a feature of this section of the book. Dr. Loisel, after discussing the general characteristics of radio-active substances, treats of the radio-activity of the air, ground and water. He also includes the measurement of the penetrating radiation and ionization in closed vessels. The large bibliography attached indicates the author's difficult task of condensing such a wide subject into such small compass.

Section II. embraces electric discharges in the atmosphere, and the quality is somewhat mixed. Prof. Mathias gives considerable space to the history, theory and practice of lightning conductors, while the measurements of intensity by Prof. C. T. R. Wilson and the estimates of frequency and variation of thunder are scarcely mentioned. The same remark applies to Vegard's recent work on the spectrum of the aurora. In discussing the electricity of precipitation, the author appears to support the theory of thunderstorms developed by Simpson, and the major portion of a chapter of thirty pages is devoted to this theory and the experiments at Simla leading up to it. Norinder's latest investigations on this subject are also adequately dealt with. Here Prof. Mesny has an excellent article on wireless telegraphy. After describing apparatus and methods of transmission and reception of wireless waves, he discusses their propagation and the part played therein by an upper conducting layer, which has again become prominent through its power of reflecting waves of short wave lengths. He concludes with a discourse on the origin and nature of "atmospherics," in which he refers at length to the work of Watt and Appleton.

Section III. deals with electric earth currents. M. Bosler gives an account of those currents due to natural causes, such as affect telegraph lines during times of magnetic disturbance. Apparently he assigns to them the cause of irregular magnetic variation of the earth. Artificial currents, such as are produced by leakage from electric mains, are dealt with by M. Girousse, who has a practical engineer's concern for the electrolysis of underground pipes, for which, he says, these currents are responsible.

Considerable value is added to the treatise by the large number of illustrations and diagrams given, and not found elsewhere under a single cover. The book shows few national prejudices, and British and American works have received ample consideration, both in the extensive bibliographies and the text. Few mistakes are noticeable: Fig. 1, page 110, is upside down; McLennan, p. 286, in the bibliography, is spelt without the "Mc," although correctly given in the text; while on p. 146, in describing Simpson's measurements of ionization, Karasjok (where the work was actually done) is stated to be in India.

The treatise is so readable, and the sectional bibliographies so complete, that no worker in atmospheric electrcity should be without such a comprehensive reference book on the subject.

R. E. W.

Luftelektrische Untersuchungen bei Flugzeugaufstiegen. Von ALBERT WIGAND. Fortschritte der Chemie, Physik und physikalischen Chemie. Band 18, Heft 5 (serie B). Berlin (Gebrüder Borntraeger), 1925. 8°. Pp. 52.

The success which has attended the work of Prof. Wigand, of Halle, in the perfecting of apparatus and methods for the reliable determination of certain atmospheric electrical elements from an aeroplane in flight indicates the great possibilities of this method for obtaining detailed

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information as to the electrical condition of the free atmosphere at frequent intervals from a network of stations. For such a purpose the aeroplane possesses certain obvious advantages over the free balloon, but there is one important disadvantage and in some other respects the technical difficulties which have to be met to ensure reliable measurements are greater in the case of the aeroplane.

It is found by the author and his collaborators that satisfactory determinations of the conductivity and the ionic content can be made by employing modified forms of Gerdien's and Ebert's apparatus. Observations made, between heights of 3.3 and 5.2 km., on two days in July, 1919, agree with earlier observations from balloons; ionization increases with height, and the positive ions are in excess of the negative. At the 5.2 km. level the space charge, *i.e.*, the excess of positive over negative charge (presumably associated almost entirely with light ions), was of the same order as that formerly determined at much smaller heights. In order to remove the necessity of a steady level being maintained by the aeroplane during the few minutes' duration of the observations just described, a method of observing, or recording autographically, instantaneous values of ionic content or of conductivity has been devised. By exposing to the full air current a condenser system of large surface area, the discharge current becomes of the order of 10^{-8} or 10^{-9} amperes and is directly measurable. Results of observations with this arrangement are not given.

The measurement of the natural electric potential gradient from an aeroplane is a more complicated matter. Difficulties arise in connection with the collector (equaliser of potential); and the electric charge, due to engine action, on the aeroplane greatly distorts the natural electric field in the immediate neighbourhood. Specially suitable forms of collector, radioactive and water-spray, are described. In the former type the geometrical form is such that, by reason of the nature of the associated atmospheric eddy formation, the action and efficiency of the collector remain tolerably constant throughout a sufficient range of air-speed. Such a collector is appropriate for use in airships to prevent dangerous accumulation of electric charge.

Contrary to expectation, the high conductivity of the engine exhaust gases does not suffice to remove the charge resulting from engine action. From the results obtained during some twenty or thirty experimental flights undertaken to extend and improve upon the data of earlier laboratory experiments by other workers, it appears that the engine develops a high positive charge, with the consequence that the normal electric field near the aeroplane is overwhelmed. The voltage developed, and therefore the charge, varies with engine performance. In the case of the machines used, with engine rates of 1,340-1,400 revolutions per minute the aeroplane potential was 1,050-1,250 volts higher than that at the level of the collector a metre or two above the 'plane. The positive charge developed is attributed to the removal of negative charge by the exhaust gases. Attempts to prevent this escape of negative charge have been unsuccessful, and the complete removal of the positive charge through the agency of an equaliser of the types at present available is impossible. The rate at which charge is removed by such an equaliser depends on the aeroplane voltage, and it may be shown that even with the most favourable arrangement of the equaliser the rate of removal of charge must eventually become inferior to the rate of generation of charge by the engine. Until an equaliser which is independent in its action of the aircraft voltage is devised this method can result only in a limit being set to the magnitude of the acquired charge. For these reasons the measurement of potential gradient by means of a single collector arranged on an aeroplane is impracticable. Such measurements could be made by arranging two collectors at different distances from

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the aeroplane and applying to the observational data corrections derived from laboratory experiments with a model apparatus.

For the determination from an aeroplane of the amount of radium emanation, RaEm, present in the atmosphere, a compact apparatus has been invented. By reason of the high speed of the aeroplane, air is caused to flow through a cooler immersed in liquid air of high oxygen content, with the result that the RaEm—or a calculable portion thereof—is condensed. Each piece of apparatus admits of three separate determinations during a flight, and each condensation operation occupies from five to seven minutes. The quantity of air from which the RaEm is condensed is determined by means of observations of the indications of a manometer connected to a form of Venturi meter, the air density being subsequently derived from meteorograph records obtained during the flight. Immediately after the termination of the flight the collected RaEm is transferred to special receptacles and the quantities are then determined by the usual laboratory methods. The data obtained from five flights near Berlin in 1923, 1924, are the earliest determinations of RaEm content of the free atmosphere at the heights reached. It was found that the amount of RaEm decreased with height and vanished at heights varying, according to the meteorological conditions, from 2 to 3.8 km. The highest value found, viz., 426 Curie/10^{18} cm^3, occurred at between 300 and 400 m. above sea level and below a temperature inversion. The fact that the RaEm content decreases rapidly with height confirms the view that it originates from radioactive matter in the earth's crust and is contrary to Bongard's supposition that the RaEm of the atmosphere is of immediate solar origin.

H. W. L. ABSALOM.

Innere Bewegungen in den Zwischenschichten des Meeres und der Atmosphäre. Von O. PETTERSSON. *Upsala, Nova Acta Regiæ Societatis Scientiarum,* Ser. IV., Vol. 6, No. 2, 1923. Pp. 43, pl.

This is a sequel to Prof. Pettersson's earlier works, the burden of which is the theory that, besides the well-known tides, there are variations in the tide-generating forces, in accordance with changing configurations, in longer and shorter periods of the Earth, Moon and Sun, which produce waves at surfaces of discontinuity both in the hydrosphere and the atmosphere. It is held that ordinary tidal theory merely treats the atmosphere as a whole, with the result that atmospheric tides appear to be negligible, taking no account of the stratification of the atmosphere, agitation of which ultimately leads to the development of cyclonic activity. In support of these views he makes much capital out of certain phrases used by Sir Napier Shaw at Hull in 1922 regarding layers in the atmosphere. According to Pettersson, at times of high tide-generating force the oceanic circulation, largely in consequence of these "between-layer" disturbances, increases in vigour, causing increased quantities of warm water to drift polewards and of polar ice to be displaced southwards, which latter during quieter periods remains pent-up in the Arctic, and this in turn affects the atmosphere, leading to sharper and more frequent discontinuities of temperature and humidity in temperate latitudes. In this way the attempt is made to coordinate the alleged tidal generation of cyclonic activity with its geographical basis in the polar front. The weak point in the theory is that there is no mathematical demonstration that these alleged internal tides do, or could, exist, though it must be admitted that the circumstantial evidence is so far good as to show close correspondence between the astronomical cycles in question and certain hydrographic and meteorological periodicities. May it be that this is the nature of the unknown force which some meteorologists, including the present reviewer (see *Journal,* Vol. 51, p. 267), think is required to assist the surface discontinuities along the polar front to generate cyclones?

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The astronomical configuration which produces the maximum of tide-generating force occurs when the lines of the moon's nodes and apsides coincide at the time of perihelion, which is the case about every 1,800 years. Then it appears that very high tides associated with very stormy weather cause disastrous inundations along the shores of the Baltic and North Sea, and as large quantities of polar ice drift southwards about these periods, the general conditions are cold and wet. The last maximum occurred in the Middle Ages. But there are various other periods, including one oscillating about 100 years, another of nine years, and the smallest of three years. In our time the "node-apside" configuration occurs near the autumnal equinox of the Northern Hemisphere for three years in a period of nine, and tables are given indicating meteorological responses during the following winters in the countries of North-Western Europe. It appears that as regards this smaller period of nine years the winter temperature is higher when the tidal action is greater, apparently in consequence of larger volumes of warm Atlantic water sweeping into the North Sea and through the Cattegat and Skager Rack into the Baltic.

But unless these periods, even if they come to be substantiated, can be brought into line with the various sunspot periods and the "thousand and one" other periodicities constantly being discovered or suspected, we very much doubt their value in seasonal forecasting. All these alleged meteorological periodicities, besides being very numerous, overlap or cut one another out in the most confusing manner, many of them run uncertain courses, dying out or unexpectedly reappearing, and in none of them are the phenomena comparable with the two grand periodicities of summer and winter, and day and night.

It will be observed that the above theory marks a reversion to the belief in the influence of the moon on the weather, though not in the crude sense of the countryman or the man in the street in relation to the monthly phases. It only shows once again how impossible it is for the man of science to answer questions with an unqualified "aye" or "nay."

L. C. W. B.

La Prévision du Temps en Agriculture. By J. SANSON. Paris (J. B. Baillière et fils), 1925. Pp. 320. 8vo. Price 10 francs.

This book on "forecasting the weather in agriculture" forms a volume of the *Encyclopédie agricole*, a series of text-books on agriculture issued in Paris. Much of it is similar in character to the *Météorologie agricole* by Klein, a good deal of the same ground being covered in the first half, which is taken up by a general description and explanation of atmospheric perturbations. This is followed by the sections more specifically devoted to forecasting, with and without the use of synoptic charts. The most interesting portions are those dealing with the issue of forecasts by means of wireless: this organization has been greatly developed within the last five years, and the country is now covered with a network of regional centres connecting with subsidiary stations. It should be added that the book is written with all the lucidity and clearness of diction that are so marked a feature of most French scientific writings.

R. H. H.

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IONIZATION IN THE UPPER ATMOSPHERE.

By Prof. S. CHAPMAN, F.R.S.

A Lecture delivered before the Royal Meteorological Society, March 17, 1926.

§1. REFLECTION OF WIRELESS WAVES.

Recent work[1] on the reflection of wireless waves in the atmosphere has given very direct proof of a high degree of ionization at high levels. It has been established by several independent investigators in this country and in America that short wireless waves, 500 metres or less, can be reflected downwards at night at remarkably small angles of incidence. Beams descending at angles of 25° or less to the vertical have been observed, and evidence has also been obtained of multiply-reflected beams, which have made two or more complete return journeys between the ground and the reflecting layer. The height of the under surface of the layer at night is found to be 90 km. or more, and it is estimated that the layer contains at least 100,000 free electrons per cubic centimetre.

Appleton and Barnett have determined the height of the layer very simply, as follows:—Electromagnetic waves of known wavelength λ are generated at a station A, and spread out in all directions. The waves travelling along the ground are gradually weakened, by spreading out and by ground absorption. The upward travelling waves meet an ionized layer and are partly absorbed, partly reflected or bent downwards. These downward waves return to the ground and are again reflected upwards. Near A the ground wave is much more intense than the reflected waves, but at 100 miles distance, at night, the two have about the same intensity, and interference occurs. The signal intensity at such a distance will be strong or weak according as the direct and reflected waves are in or out of phase; if their paths are of lengths a, a' respectively, the waves will be in phase or not according as n, given by $n\lambda = a' - a$, is an integer or half an odd integer. Small variations of a and a' will much affect the signal intensity, so that reception will be uncertain; or, if a and a' are constant, and λ varies, the signal intensity will fluctuate considerably. Appleton and Barnett varied λ slightly and observed the corresponding change in n by noting the number of cycles of increase and decrease of intensity of reception; thus, if λ is changed to λ', n becomes n', and $n - n' = (\lambda' - \lambda)(a' - a)/\lambda\lambda'$. In this equation $n - n'$, a, λ, λ' are all measurable, so that a' can be deduced. In a typical experiment, λ was about 390 metres, $\lambda' - \lambda$ was 7 metres, a was 140 km., and $n - n'$ was 4.5. The resulting value of a' is about 240 km., and

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the corresponding height of the top of the path of the reflected wave is therefore 80 or 90 km. The estimate of height obtained in this simple way has been confirmed also by measurements of the inclination of the downward ray.

The reflection in the ionized layer is not perfectly sharp. It is produced by ions which are set in oscillation with the frequency of the waves, causing an increase in the velocity (v) of wave-propagation. The energy received by the ions from the waves is mainly converted into heat energy when the ions collide with the gas molecules, and thereby the energy of the waves is partly absorbed, the more rapidly, the denser the gas in the layer. At 80 km., however, the interval between successive collisions of an ion is long enough to allow several oscillations in the case of short waves.

The increase in v is greater, the greater the number (N) of ions per c.c. As a wave front passes obliquely upwards into the layer, N, and therefore also v, increases, and the upper part of the wave front, by travelling onward more rapidly than the lower part, is bent forward. The wave path thus becomes curved, and if N is great enough the rays are finally bent downward again.

In the absence of the earth's magnetic field,[2] and neglecting absorption, v is given by

$$\frac{v^2}{c^2} = \frac{1}{1 - 4\pi Ne^2/m\omega^2}$$

where c is the undisturbed velocity of propagation (*i.e.*, the velocity of light), e, m are the charge and mass of the effective ions, and ω is the angular frequency of the waves ($=2\pi c/\lambda$). The value of $4\pi Ne^2/m\omega^2$ is usually small compared with unity. If, however, there is a magnetic field (of intensity H, say), it will deflect the moving ions, altering the value of v, and changing the plane of polarization of the waves.[3] The new value of v is obtained by substituting $\omega^2 - \omega_0^2$ for ω^2 in the above formula, where ω_0 is the angular velocity with which the ions can freely circle or spiral round the lines of magnetic force; ω_0 is independent of the radius r of this circular motion, being given by $m\omega_0^2 r = eH\omega_0 r/c$, *i.e.*, $\omega_0 = eH/mc$. If the waves are of such length that ω is nearly equal to ω_0, their velocity will be greatly modified, and this result gives a means of determining whether the effective ions are electrons or charged molecules. For electrons ω_0 corresponds to a wave length of about 200 metres, in the case of the earth's magnetic field; for molecular ions the corresponding wave length is at least 300,000 metres, and the magnetic influence on v would be negligible for all wave lengths if such ions were alone present. Observations of reflection at night, for wave lengths about 200 metres, indicate that the effective ions are free electrons. Positive molecular ions must also be present, of course, but will take only a negligible share in the bending of the waves.

For waves as short as 20 metres, ω will be 10 or 11 times as great as ω_0, and the magnetic effect on the propagation is negligible. By observing the reflection of such waves it is possible to estimate the value of N at the level at which the waves are travelling horizontally. Consider a wave traversing a path ABCDE between

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two stations A, E, the parts AB, DE being straight, corresponding to passage through non-ionized air below the under surface BD of the reflecting layer (Fig. 1); C will denote the top of the curved path BCD in the layer. Assuming the layer to be horizontally stratified, so that N is a function of height only, then along the curved path $\mu \sin i$ will be constant, where $\mu\,(=c/v)$ is the index of refraction, and i is the inclination of the ray to the vertical. At B, $\mu=1$ practically, and $i=i_0$ (say); at C the ray is horizontal, and $\sin i=1$. Hence the value of μ at C is given by $1 \sin i_0=\mu \,.\, 1$ or $\mu=\sin i_0$. Hence

$$\cos^2 i_0=1-\sin^2 i_0=1-\mu^2=1-c^2/v^2=4\pi Ne^2/m\omega^2.$$

For these short waves the intensity of the direct wave travelling along the ground is much reduced beyond 100 miles, but at about 400 miles the reflected wave appears with appreciable strength. Taking AE as 400 miles, and the height of B or C as 80 km. or

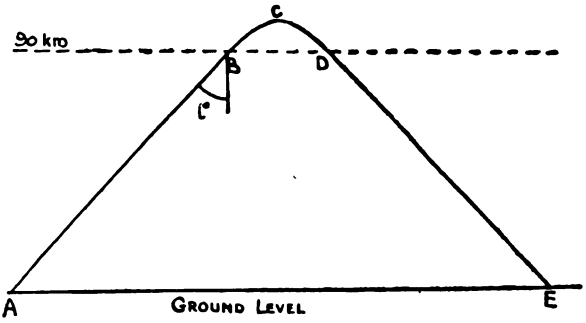

FIG. 1.—Reflection of a wave by the ionized layer.

50 miles, $\cos^2 i_0$ is about 1/17, and since $e=4.8 \,.\, 10^{-10}$ e.s.u., $m=9.0 \,.\, 10^{-28}$ gr., and $\omega=10^8$, we have $N=10^5$ approximately. This is a lower limit for N, since absorption has been ignored, and if taken into account would increase the estimate of N.

The above results refer to the night hours. During the day short waves are not appreciably reflected at these high angles, though glancing reflection occurs, enabling long waves, in particular, to be transmitted to great distances with much higher intensity than can be explained by simple diffraction round the curved surface of the earth. The theory[4] of this glancing reflection is much more complicated than that of high-angle reflection, but it successfully explains Austin's simple empirical formula for the variation of intensity with distance. It indicates also that in the daytime the ionized layer extends lower down than at night, its under surface being at 40 or 50 km. At this level the ionic paths are only about 1/1,000 as long as those at 80 or 90 km., and absorption is increased in the case of waves impinging at high angles, which penetrate the layer more deeply than do glancing rays. This accounts for the faintness of high-angle reflection by day.

§ 2. Comparison of Wireless and Magnetic Results.

The "wireless" evidence thus indicates that the upper atmos-

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phere is ionized in a layer of unknown thickness, which extends down to 40 or 50 km. above the ground by day, and to about 90 km. by night, the rise of the under surface being due to the progressive re-combination of the ions at the lower levels after sunset. The electron density at about 90 km. at night is at least 100,000 per c.c. The greater thickness of the layer by day is obviously due to solar action.

The existence of a highly ionized atmospheric layer has long been inferred also from the study of the daily changes in the earth's magnetic field, and where the inferences from the wireless and magnetic date overlap, they are in at least qualitative agreement. The daily magnetic variations are attributed to electric currents flowing in a highly conducting layer, which are impelled by electromotive forces induced by tidal or quasi-tidal motions of the air in the presence of the earth's magnetic field. The variable rate and amplitude of the magnetic changes must be due mainly to variations in the conductivity of the atmospheric layer, since the other factors involved in the phenomenon are nearly constant. By such considerations it is deduced that the conductivity of the layer in question is greater by day, and at low latitudes, and in summer, than at night, or in higher latitudes, or in winter. These differences can be briefly summed up in the statement that the conductivity is greatest when and where the sun's rays fall most directly, and for the longest continuous period, upon the atmosphere; and that after sunset the conductivity quickly diminishes. The wireless evidence is insufficient as yet to indicate all these changes, but it confirms the change as between day and night.

In other respects the wireless and magnetic evidence are complementary. The latter gives no indication of the situation of the layer, but it affords an estimate of the total conductivity, that is, of σ, the specific conductivity, multiplied by d the thickness of the layer. An average value of σd is 3.10^{-6} e.m.u., though at the equator, at midday, at sunspot maximum, a higher value is likely. Even the value 3.10^{-6} is, however, so great as to have seemed difficult to account for, and its apparent improbability has been urged as an objection against the above theory of the diurnal magnetic variations. It is therefore important to examine the new wireless evidence on this point, and particularly the estimate of the degree of ionization N, at night, which it affords, viz., $N=10^5$ electrons per c.c. at 90 km. From this, knowing the density of air at that height, the specific conductivity σ can be calculated; using the approximate formula $\sigma=Ne^2l/mV$, where V is the velocity of the electrons and l their mean free path, and taking $V=10^7$ cm./sec., and $l=10$ cm., $e=1.6\,.\,10^{-20}$ e.m.u., $m=9.0\,.\,10^{-28}$ gr., we get $\sigma=3.10^{-14}$ e.m.u. This refers to the night, when σd will be less than 3.10^{-6}, so that d must be less than $3.10^{-6}/3.10^{-14}$ or 10^8 cm., equal to 1,000 km. This upper limit for d is certainly improbably large, but it is over-estimated by taking a lower limit of N, and as d may quite well be 100 km. or more, the degree of accordance between the wireless and magnetic data for the conducting layer may be considered satisfactory in the present state of knowledge.

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§3. The Cause of the General Ionization of the Upper Atmosphere.

Since the high degree of ionization in the upper atmosphere depends so much upon the directness or absence of sunlight, it must be due mainly, if not entirely, to solar action, and there is no need to look for other causes such as highly penetrating radiations or thunder-cloud action. This conclusion is further confirmed by the fact, clearly indicated by the magnetic data, that the conductivity is greater by about 50 per cent. at sunspot maximum than at sunspot minimum. It may be hoped that this also will in time be confirmed by wireless measurements. This large variation of intensity is of great interest for its bearing on the question as to how the sun ionizes the air in the daytime. The most natural hypothesis is that the ions are produced by solar radiation, necessarily at the ultra-violet end of the spectrum; if so, the radiation in that spectral region must vary by about 100 per cent. during the solar cycle (since—see below—the rate of ionization, measured by the number of ions q produced per cc. per sec., must be proportional to N^2 and therefore to σ^2). The solar radiation in the visible region varies at most by a few per cent., and no independent evidence is yet available for so striking a change in the ultra-violet radiation as the magnetic data appear to require.

Even apart from this interesting question, it has been doubted whether there is enough energy in the ultra-violet region to account for the observed ionization. Swann[5] examined this point in 1916, and concluded that the supply was quite inadequate—only about a millionth of what is required. In the light of present knowledge, however, this drastic conclusion seems unjustified, and I find, in fact, that the available energy is of the right order of magnitude to explain the observed conductivity. As the question is of importance, it will be briefly examined.

The number of ions present per cc., N, is connected with the number q of ions produced per cc. per second, at the same level, by the equation

$$\frac{dN}{dt} = q - \alpha N^2,$$

where the term on the left, representing the rate of increase of N, is equated to q, the rate of production, less the rate of recombination, which is proportional to N^2; the coefficient α is called the coefficient of recombination. When the number of ions present is steady, $q = \alpha N^2$, showing that q must vary as N^2 or σ^2, since σ is proportional to N.

The value of α is about 10^{-6} in the atmosphere near the ground, and Swann assumed that its order of magnitude would be the same in the upper atmosphere, as a very rough theory of recombination would indicate, for ions of the same kind (*i.e.*, mainly molecular ions, such as occur near the ground). This assumption seems, however, to be very wide of the truth, judging from the wireless determination of N at night. For, taking the time $t = 0$ at sunset, after which we may suppose $q = 0$, the solution of the above equation is

$$N = \frac{N_0}{1 + N_0 \alpha t} \qquad \text{or} \quad N_0 = \frac{N}{1 - N\alpha t}$$

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where N_0 is the value of N at sunset. We know that $N=10^5$ even several hours after sunset, *e.g.*, for simplicity, at time $t=10^4$ sec. (about three hours); substituting in the first of these equations, we have $10^5=N_0/(1+10^4\alpha N_0)$ and if α is 10^{-6}, then, since N_0 is greater than N, $10^4\alpha N_0>1000$, and therefore large compared with unity. Hence the formula reduces to $10^5=1/(10^4\alpha)$ which is quite inconsistent with $\alpha=10^{-6}$. For times such that $N_0\alpha t$ is large compared with unity, since the above formula reduces to $N=1/\alpha t$, we can calculate α from the corresponding values $N=10^5$, $t=10^4$, giving $\alpha=10^{-9}$, *i.e.*, one thousand times smaller than Swann's value.

The impossibility of $\alpha=10^{-6}$ can also be seen from the second formula, which indicates that N_0 would have to be infinity in order to account for a value N at time t such that $1-N\alpha t=0$; thus if $N=10^5$, and $\alpha=10^{-6}$, $t=10$ secs., showing that even very intense ionization at sunset would fall to the value 10^5 after 10 seconds if α were 10^{-6}, so that after 100 or 1,000 seconds the observed ionization would be far less than that actually observed several hours after sunset.

It has been assumed here that only electrons and positive molecular ions are present, but it may readily be seen that the argument is only strengthened if negative molecular ions are also present.

The fact that the under surface of the ionized layer rises during the night suggests that α decreases with increasing height, *i.e.*, the rate of recombination is less at the greater heights, and the ionization persists longer after sunset at such heights.

It appears therefore that at about 90 km., α is of order 10^{-9}. The rate of production of ions during the day, q, must be of order αN^2, where N is the daytime value of the ionization. Swann took the value 3.10^{-6}, already quoted, for σd, and took d as 3.10^7 (300 km.), giving $\sigma=10^{-13}$; this corresponds to $N=10^6$ at about 100 km. height, and less (proportional to the pressure) at greater heights. Consequently $q\leqslant 10^{-9}\,.\,10^{12}=10^3$. In a column of air of 1 sq. cm. cross section, and 300 km. in height, the number of ions to be produced per second is therefore less than 3.10^{10}. Swann, however, estimated that a million times as many would be required, the discrepancy arising partly from his value of α, which was 1,000 times too great, and partly from the tacit assumption that the effective ions were molecular and not free electrons; this made his estimate of N^2 at least 1,000 times too great. When the requisite rate of production of ions is reduced to the value here calculated, the energy of the available ultra-violet radiation appears quite sufficient; taking Swann's figures (*i.e.*, assuming that the sun radiates like a black body at 6,000° absolute, and that only the radiation of wave length less than 1,350 Å—corresponding to an ionization potential of 9 volts*—is available for ionization) it appears that about 10^{12} ions could be produced per second in each column of air of 1 sq. cm. cross section.

* Light of wave length λ—in Ångstrom units—is absorbed and emitted in quanta of energy equal to that attained by an electron which falls through a difference of potential of V volts, where λ and V are related by the equation $\lambda V=1.234.10^4$. Thus V is greater, the shorter the wave length.

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§4. The Mode of Ionization of the Air.

While the difficulty raised by Swann is thus removed, recent work by H. D. Smyth[6] on the ionization of nitrogen and oxygen by electronic impacts might seem to raise it anew in an acute form. Smyth found that the lowest ionization potentials for these gases are 16.9 and 15.5 volts respectively, corresponding to maximum wave lengths of radiation, for ionization, of 730 Å and 796 Å. The fraction of the solar radiation of wave length below these limits is less than 10^{-4} times that at 1,350 Å, as assumed by Swann.

Whereas Smyth's work indicates that 15.5 volts are required to ionize air, Hughes[7] and others have undoubtedly ionized air by radiation of wave length not less than about 1,350 Å, corresponding to 9 volts. The solution of the discrepancy seems to lie in the fact that in Hughes' experiments the molecules had available for absorption an ample supply of radiation of wave length longer than 1,350 Å, so that it was possible for them to absorb in successive stages the energy necessary for ionization, though there was not radiation of sufficiently short wave length to effect ionization in one operation alone, as was done, by electronic impacts, in Smyth's experiments.

It seems not unlikely that in the upper air the ionization is connected with the formation of ozone, which is known to exist in considerable quantities in the upper atmosphere. Ozone (O_3) is formed on absorption by oxygen of radiation in the region about 1,400 Å; this implies that some of the oxygen molecules (O_2) are dissociated. If the energy of such radiation is insufficient by itself to effect ionization, as Smyth's work suggests, the oxygen atoms formed must be neutral. These combine with other oxygen molecules to form ozone molecules, which then absorb practically all the remaining ultra-violet radiation (of much greater amount) up to about 3,000 Å. It is, of course, by this absorption (which has been proved to occur in the upper atmosphere, and not either at the sun or in the lower atmosphere) that the presence of ozone in the upper air has been recognized and its moment measured. The suggestion here made is that the observed ionization is associated with the further stage of absorption, by ozone—a process which, in the aggregate, abstracts about 5 per cent. of the total energy of solar radiation falling on the earth. According to the measurements of Fabry and Buisson,[8] confirmed by Harrison and Dobson,[9] the ozone is equivalent to a layer 3 mm. thick at normal temperature and pressure; hence the number of molecules of ozone in a complete column of air of 1 sq. cm. cross section is about 10^{19}. If, as calculated above, there are about 10^6 electrons per cc. in a column 300 km. high, it is only necessary to suppose that 3.10^{13} ozone molecules, that is, three in a million, are ionized.

This part of the discussion may be briefly summed up as follows. We know that the atmosphere is highly ionized by the sun in the upper layers, but do not know definitely what constituent of the air is the one ionized, or what is the ionizing agent. We know, however, that the sun's ultra-violet radiation is absorbed mainly by ozone, and if, as the above discussion shows to be quantitatively possible, the ultra-violet radiation is the cause of the

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ionization, the latter must be effected by the ozone absorption, and ozone must be the ionized constituent.

Against this is to be set the apparent unlikelihood of a large increase in the ultra-violet radiation at sunspot maximum, such as seems required by the magnetic data. But the only alternative source of ionization is corpuscular radiation from the sun, which falls on the sunlit hemisphere without deflection by the earth's magnetic field. Such corpuscular radiation must therefore be electrically neutral (whether ionized or not). It is not improbable that the sun does to some extent emit such corpuscular radiation, but at present we have no definite knowledge of it; in any case it seems *á priori* unlikely that its order of magnitude should, like that of the ultra-violet radiation, be of just about the right order of magnitude to explain the observed ionization. The theory outlined above would therefore seem the most probable one in the present state of our knowledge.

§5. Ionization Associated with Auroræ, in High Latitudes.

Besides the ionization already considered, the study of irregular magnetic disturbance indicates that, from time to time, the air is rendered much more conducting in particular regions, especially in high latitudes. The increase affects the dark hemisphere as well as the sunlit one, and when intense it is associated with auroræ. The polar situation of auroræ, and their connection with disturbances on the sun's surface, prove that the cause lies in electrically charged corpuscular radiation from the sun; only such radiation, which is deflected towards the polar regions by the earth's magnetic field, can impinge on the earth on the dark as well as on the sunlit hemisphere. Here, therefore, the ionization cannot be attributed to ultra-violet radiation.

The lower limit of height of the aurora, about 90 km., thus represents the limit of penetration of the solar corpuscles. The nature of the latter, and even the sign of the charge, are unknown. Birkeland supposed them to be high-speed electrons (or β rays) from the sun, and Vegard also seems now to adopt this view, though for a time he believed them to be α particles. There is great difficulty, however, in either hypothesis, on account of the high ratio of charge to mass. Such corpuscles could scarcely be ejected from the sun in considerable numbers without drawing charges of opposite sign after them from the highly ionized sun's atmosphere. Also, even if emitted, they would tend to be dispersed sideways with great rapidity by their mutual repulsions. It is much more likely that the stream consists of oppositely charged ions in nearly (though not quite) equal numbers. The mechanism of emission of such a stream can be pictured in some detail, owing to recent advances in the theory of the solar atmosphere. The latter is known to be supported mainly by radiation pressure in its upper layers; for example, the ionized calcium atoms whose presence is revealed by the chromospheric spectrum are continually receiving upward impulses, one at each absorption of a quantum of outward-flowing light; the radiation is re-emitted after a brief interval, but in random directions, so that there is no resultant reaction from the emissions.

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In the excited condition, between absorption and re-emission, the atom is incapable of absorbing a second such quantum, and it is subject only to the downward acceleration of gravity. The atmosphere takes up such a distribution of density that the atoms pass rapidly upwards and more slowly downwards at equal resultant rates, a somewhat delicate equipoise being thus maintained. In disturbed regions this equilibrium state appears to break down, and clouds of (positive) ions may be impelled outwards by radiation pressure till they acquire a speed sufficient to remove them altogether from the sun's influence. They will, however, drag after them enough free electrons to reduce the ratio of charge to mass to a low value, much below that for α particles. Since the positive ions receive the outward impulses, it seems likely that the resultant charge is positive. This view is on the same general lines as that proposed by Lindemann[10] in 1920, except that the particles were initially neutral, being expelled by the radiation which ionized them; but it has been shown[11] that a neutral ionized stream would not be sufficiently deflected by the earth's magnetic field to explain the polar incidence of auroræ.

The above hypothesis seems to remove, or at least to diminish, the difficulty of explaining the rather large angular radius θ of the auroral zone. Störmer proved that a solar particle of charge e, mass m and velocity v could not impinge on the earth at a greater angular distance from the pole of the earth's magnetic axis than θ, where

$$\sin^2\theta = 2a\left(\frac{mv}{Me}\right)^{\frac{1}{2}}$$

where M is the magnetic moment ($8.5 \cdot 10^{25}$) and a the radius (6.10^8 cm.) of the earth. Ordinarily auroræ are observed up to a radius of about 23° from this magnetic pole, and at times of great magnetic disturbance the angular distance is much greater still. But for the high speed electrons (β rays) considered by Birkeland and Störmer θ is only 3° to 5°, while even for α particles it is not more than 18°. To account for the greater values of θ actually observed, Störmer has suggested that the zone of precipitation is drawn downwards towards the equator by the magnetic influence of a stream of corpuscles curving round the earth in or near the equatorial plane. But this hypothesis is open to the objection, first stated by Schuster in another connection, and never satisfactorily answered, that a stream of like charges, possessing an appreciable magnetic field (*e.g.*, of magnitude 40γ as in this case) could not maintain itself owing to the mutual repulsion of the charges. A simpler solution is to suppose that the solar streams have no appreciable magnetic field (and there is no evidence suggesting that they do exert such a field), but that the ratio m/e for the stream is many times greater than that for a molecular ion. For example, taking $v = 8.10^7$ cm. per sec. (the value adopted by Lindemann in the paper cited, though we have no real knowledge as to its value) the ratio m/e required to make $\theta = 23°$ is about 160 times that for the positive hydrogen ion. For $\theta = 45°$, the ratio must be about 1,800 times that for the hydrogen ion. On this view, the greater the auroral intensity and therefore the denser the stream of corpuscles from

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the sun, the smaller will be the ratio of unbalanced charge to mass.

§6. The Auroral Ionization and Spectrum.

Whatever may prove to be the nature of the solar corpuscles, the luminosity which they produce is likely to be due not to their own characteristic radiation, but to that of the gases in the atmosphere; for each incoming particle is likely to excite a great many molecules of the atmosphere—of the order 100 or more—on its downward path. The spectrum of the aurora therefore constitutes valuable information regarding the composition of the upper atmosphere, though unfortunately it can only partly be interpreted at present.

The spectrum certainly consists largely of the so-called negative bands of nitrogen, and band spectra are known to be due to molecular emission of light, as distinct from atomic emission. Moreover Wien[12] has recently found that the molecules which emit these "negative bands" are ionized, positively charged molecules. This is in full accord with Smyth's study of the ionization of nitrogen by electronic impact, which showed that the singly charged molecular ions are the most easily produced, with a potential of 16.9 volts; the next ionization potential is 24.1 volts, which produces doubly charged nitrogen *atoms*, while 27.7 volts are required before singly charged atoms are obtained. In these circumstances the molecular bands would be expected to appear more prominently than the arc and spark atomic spectra, and indeed it is uncertain whether any lines from the latter spectra appear in the auroral light.

Smyth (*l.c.*) also showed that the ionization potentials for oxygen closely resemble those for nitrogen, being 15.5, 22.5 and 23 volts respectively for the singly charged molecular ion, the doubly charged atomic ion, and the singly charged atomic ion. It is uncertain whether any of these ions reveal themselves in the auroral spectrum; it may well be that oxygen is more readily dissociated by impact into neutral atoms, as would appear from the formation of ozone by absorption of radiation (about 1,400 Å) equivalent in potential to 8 or 9 volts. The presence of neutral oxygen atoms in considerable numbers in auroræ seems required if, as seems reasonable, the claim of McLennan and Shrum[13] to have produced the famous green auroral line in pure oxygen is admitted. This line is of great sharpness, as Babcock[14] has shown in his delicate interferometer measurement of its wave length ($5577.350 \pm .005$ Å); hence, since molecules give rise to band spectra, it must be emitted by atomic oxygen; but the spectra of singly and doubly charged positive atoms of oxygen are well known, and do not contain this line; the emitting atom must therefore be neutral (or, possibly, negative). These conclusions are necessarily provisional until the green auroral line has been more fully studied in association, if possible, with other lines; but they seem far more probable than the contrary hypothesis of Vegard,[14] that the auroral spectrum results from frozen crystals of nitrogen in the upper atmosphere. Apart from the fact that the spectroscopic evidence for the claim is extremely weak owing to the low dispersion used, the hypothesis encounters many formidable difficulties, which have been con-

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vincingly set out by Atkinson.[15] The foremost objection, probably, is the extremely low temperature (35° absolute) which is demanded at 90 km. and above.

The circumstances under which the green auroral line is emitted by oxygen atoms are apparently very varied, since it occurs not only under the great and immediate stimulus of corpuscular impacts during auroræ, but also, all over the earth, during the night. In particular, Lord Rayleigh[16] has shown that this "non-polar aurora" is more intense in low than in temperate latitudes, so that it occurs in places where, during the night, there can hardly be any extra-terrestrial stimulus in operation, either radiation or corpuscles. If the green line is due to atomic oxygen, the presence of such atoms at night seems explicable only by supposing them to be due to the break up of ozone molecules, which must certainly proceed steadily through the night. It is possible that when the ozone molecule breaks up, the one atom (at least) of oxygen which is set free may be in an excited condition just after separation. If so, it will emit light of a definite character, depending only on the way in which the ozone molecule disintegrates. This definite process, occurring in rarefied regions where the electric fields of the atoms and molecules do not affect each other, may account for the apparent lack of association of the green auroral lines with other lines—a natural phenomenon not yet imitated in the laboratory, where much more energetic stimulus is applied, as by McLennan and Shrum, to produce the green line, which then appears with many other oxygen lines.

The latter authors have proposed a different hypothesis to account for the very definite excitation apparently available during auroræ to produce the green line; they suggest that this excitation is due to metastable helium. But this requires the helium itself to be first stimulated by 20 volts or more, in which case the auroral spectrum should show helium lines, which it does not do. There is, indeed, no positive evidence for the existence of helium at auroral levels, and if, as is quite likely, the atmosphere is sufficiently mixed by winds up to at least 40 or 50 km. to overcome diffusive separation of the various atmospheric gases, there can only be a very small percentage of helium at 90 km. (about 0.1 per cent.).

On the present view, the green line is produced in the non-polar auroræ by the break up of ozone molecules, but whether by the ionized or non-ionized ozone molecules is not clear; the latter, of course, are by far the more numerous. Similarly, although during polar auroræ it is likely that oxygen molecules are dissociated and ozone molecules are formed, it is not clear whether the ozone molecules must undergo some further process, of excitation or ionization, before they can give rise on disintegration to atoms emitting the green line: or whether, indeed, ozone is necessarily involved in the production of the green auroral line in polar auroræ. There appears to be scope here for laboratory experiments on ozone to throw light on these doubtful points. Measurements of the ozone content of the upper air in auroral latitudes would also be of great interest.

Associated with these problems are those of the marked variations in the intensity of the light of the night sky, in the red and blue as well as in the violet regions of the spectrum, as

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measured by Lord Rayleigh; and in the amount of ozone, as determined by Dobson and Harrison. The correlation of the ozone content with the pressure at the height of 10 km. is one of the most interesting observational results which has recently been obtained in this field. Everyone interested in the difficult but attractive problems of the upper atmosphere must rejoice at the new avenues of research now being vigorously explored by co-operative effort, in wireless propagation, the non-polar aurora, the ozone content of the atmosphere, and in other directions. At present they may at times appear only to create more problems than they solve, but it may be hoped with some confidence that before many years have passed they will afford a much more clear and connected picture of upper atmospheric phenomena than we now possess.

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At the close of the meeting, the PRESIDENT (Sir Gilbert T. Walker) offered Prof. Chapman on behalf of the Fellows their most hearty thanks for a lecture of excellent ability, extreme lucidity and of the greatest interest.

Memories Patxot.

M. Raphaël Patxot i Jubert has, since 1922, offered prizes yearly for the best essays submitted, giving the results of original work in either the domain of science or mathematics.

The subject for the fifth contest is the meteorology of the western Mediterranean, and more particularly that of the coast of Catalonia. Essays may be submitted in English in either of the Latin languages or in Catalonian. The competition closes December 31, 1927. Further particulars can be obtained from M. Patxot, at Rue de la Cucurulla 1 and 3, Barcelona.

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THE DRIEST AND WETTEST YEARS AT INDIVIDUAL STATIONS IN THE BRITISH ISLES, 1868 TO 1924.

By JOHN GLASSPOOLE, M.Sc., Ph.D.

[Received December 9, 1925—Read April 21, 1926.]

A consideration of the rainfall of any locality generally entails a knowledge of the average annual fall. The data collected by the British Rainfall Organization enable such averages to be calculated for numerous places over the British Isles. The distribution of average rainfall is conveniently shown on a map and reference may be made to the following maps of annual rainfall :—

(1) For the whole British Isles on a scale of 16 mi. to 1 inch (1,000,000 : 1);[1]
(2) For the whole British Isles on a scale of 60 mi. to 1 inch (4,000,000 : 1);[2]
(3) For Wales on a scale of 16 mi. to 1 inch (1,000,000 : 1);[3]
(4) For the counties of Bedford, Essex, Hampshire, Kent, Lincoln, Northampton, Nottingham, Oxford, Suffolk, Surrey, Sussex and Yorkshire (East Riding) on a scale of 10 mi. to 1 inch.[4]

Information as to the fall of the driest and wettest years is also of importance and the object of this paper is to show the minimum and maximum falls recorded and the years in which they occurred. It is convenient to deal with the rainfall at each station in these extreme years as a percentage of the average fall and the standard period 1881 to 1915 has been adopted. For the purpose of the present paper, some 300 long records were available. These records have already been critically examined for reliability[5] and only such records as appear to be homogeneous were utilised. The method consisted essentially of examining the records in relation to those from neighbouring stations on three series of maps, showing as a percentage of the average 1881 to 1915 (*a*) the rainfall of each year, (*b*) of each 10 years and (*c*) of each 35 years in the whole period under discussion. Sufficient data were available to deal with the 57 years 1868 to 1924. Where the records did not extend over the whole period the annual maps were examined to see if by any chance the extreme years might have occurred

[1] Published by W. and A. K. Johnston, Ltd., Edinburgh (1924).
[2] In the course of publication by the Royal Meteorological Society in a Rainfall Atlas.
[3] Published by the Ordnance Survey in *An Agricultural Atlas of Wales*, 1921. In the case of (1), (2) and (3) the original rainfall maps were prepared by the Meteorological Office. Map (1) also shows hypothetical lines for the rainfall over the sea.
[4] Published by the Geological Survey of England and Wales and prepared by Dr. H. R. Mill.
[5] The methods adopted are set out in *Fluctuations of Annual Rainfall, Three Driest Consecutive Years*, by J. Glasspoole, *Proc. Inst. Water Engin.*, 1924, and in *A comparison of 35 year Rainfall Averages over the British Isles for Different Groups of 35 years falling in the period 1868 to 1921, by* J. Glasspoole; *British Rainfall*, 1923.

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outside the period of observation. In such cases the records were not utilized. For some 250 stations the falls of the driest and wettest years in the series have been extracted and these details are set out in Table I. The maps, Figs. 1, 2, 3 and 4 are based on these statistics. They indicate, respectively, for any part of the British Isles (1) the driest year, (2) the wettest year, (3) the percentage fall in the driest year and (4) the percentage fall in the wettest year. Reference was also made in the preparation of the maps, Figs. 1 to 4, to the series of annual percentage maps.[6]

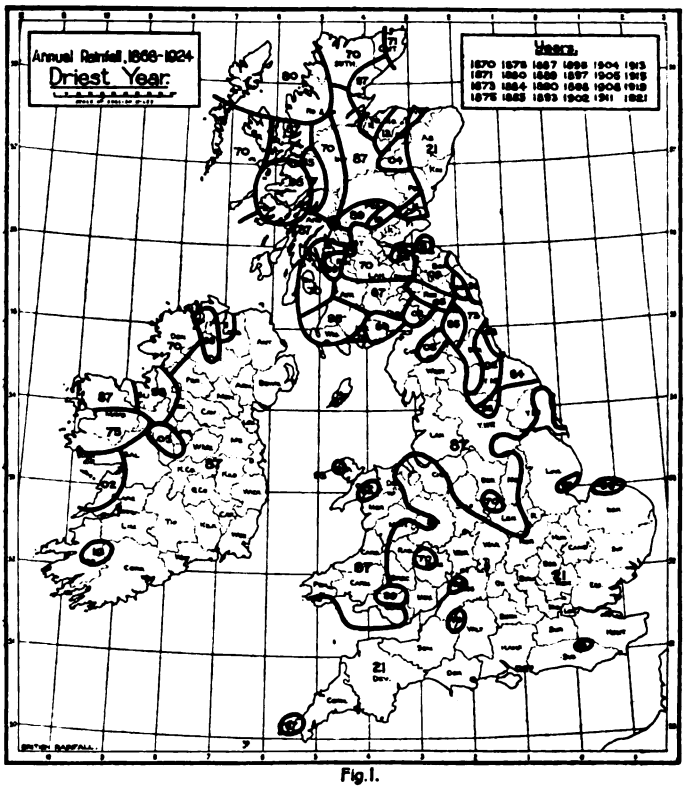

Fig. 1.

Thus in Fig. 3 the lines in the south-east of England were drawn to agree with the annual percentage map for 1921, which was constructed from fuller data.

It should be emphasized that the maps are constructed from values for individual stations. The average rainfall varies from place to place, so that the percentages as read off from the maps are related to the average rainfall at each particular point and cannot be compared, the one with the other, if actual amounts are required. The importance of this is emphasized by a comparison

[6] Maps showing the rainfall of each year 1868 to 1923, as a percentage of the average were prepared and are being published by the Royal Meteorological Society in a Rainfall Atlas.

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of the falls of the wettest years at Stanground Sluice in Cambridgeshire and at Borrowdale (Seathwaite) in Cumberland. In each case the wettest year was 1872, but at Stanground Sluice the fall was 51 per cent. or 10.29 inches above the average, while at Seathwaite the fall was 38 per cent. or 49.12 inches above the average. In actual rainfall the excess at Seathwaite was nearly five times as much as that at Stanground Sluice.

Dealing with the figures given in Table I., the greatest deficiency was 51 per cent. at Haslemere (Courts Hill) in Surrey

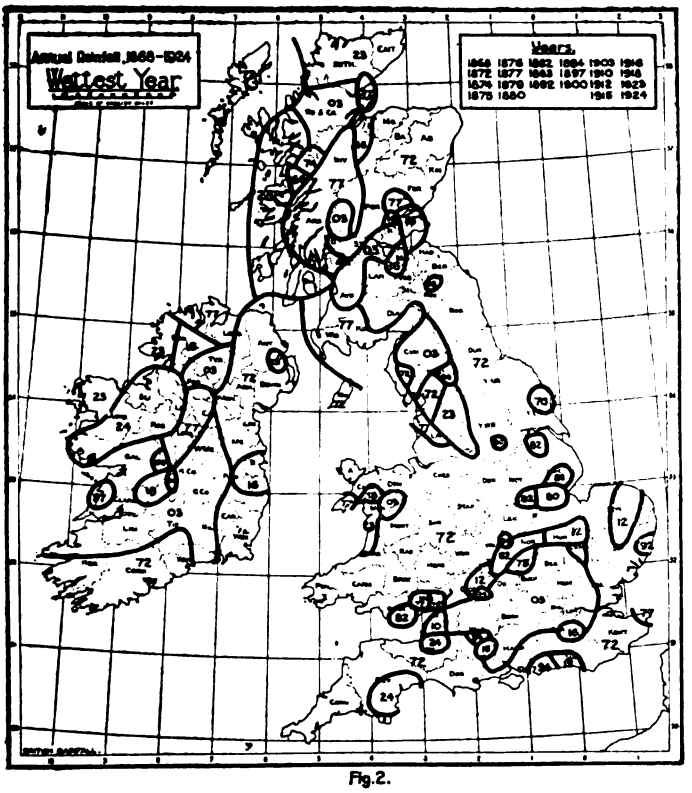

Fig.2.

in 1921; numerous stations in the south-east of England showed deficiencies of 50 per cent. in that year. The greatest excess at any individual station was 80 per cent. at Osmotherley, near Northallerton, in 1872, this figure being well supported. At Osmotherley the range was from 69 per cent. in 1902 to 180 per cent. in 1872, a range of as much as 111 per cent. of the average.

The annual rainfall at individual stations in the British Isles has varied from 10 inches in 1921 at Margate to more than 240 inches. This amount was exceeded at The Stye in Cumberland in 1872 and 1923, at Ben Nevis Observatory in Inverness in 1898 and at Llyn Llydaw on Snowdon in 1909. The fall for 1923 at The Stye was reported as 247.30 inches.

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The Driest Years over the British Isles.

From Fig. 1 it is apparent that the years 1887 and 1921 were the driest over a far larger part of the British Isles than any other year. Each area was measured on the draft map with a planimeter and those having the same driest year were grouped together. The total area of the British Isles was taken as 100 units so that in Table II. the area, over which any of the specified years was the driest, is set out as a percentage of the whole area.

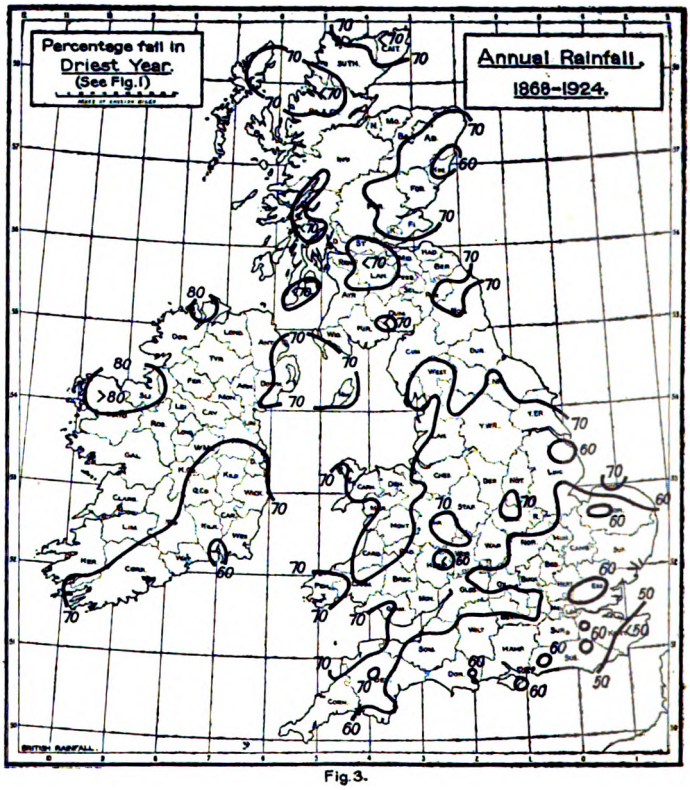

Fig. 3.

Thus the year 1887 was the driest in the series 1868 to 1924 for over 40 per cent. of the British Isles. The three years 1870, 1887 and 1921 with 8, 40 and 31 per cent. respectively, account for 79 per cent. or nearly four-fifths of the whole British Isles. In all as many as 24 out of the 57 years appear as the driest somewhere in the British Isles. In each of 14 years only a small part of the British Isles, less than 1 per cent. of the whole area, is affected.

The proportion set out in Table II. was not maintained throughout the various countries. In England the year 1921 was the driest over as much as 67 per cent. of the whole area, the year 1887 over 22 per cent. and the two years 1873 and 1902 over about

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2 per cent. each. In Wales the two years 1887 and 1921 with 61 and 31 per cent. respectively accounted for nearly the whole area. In Scotland the years with the largest areas were 1887, 1870, 1895 and 1880 with 26, 23, 13 and 10 per cent. respectively. The year 1921 was the driest over only 8 per cent. of Scotland. In Ireland the year 1887 was the driest over as much as 77 per cent. of the area. The next years were 1870, 1875 and 1893 with only 5, 5 and 4 per cent. respectively.

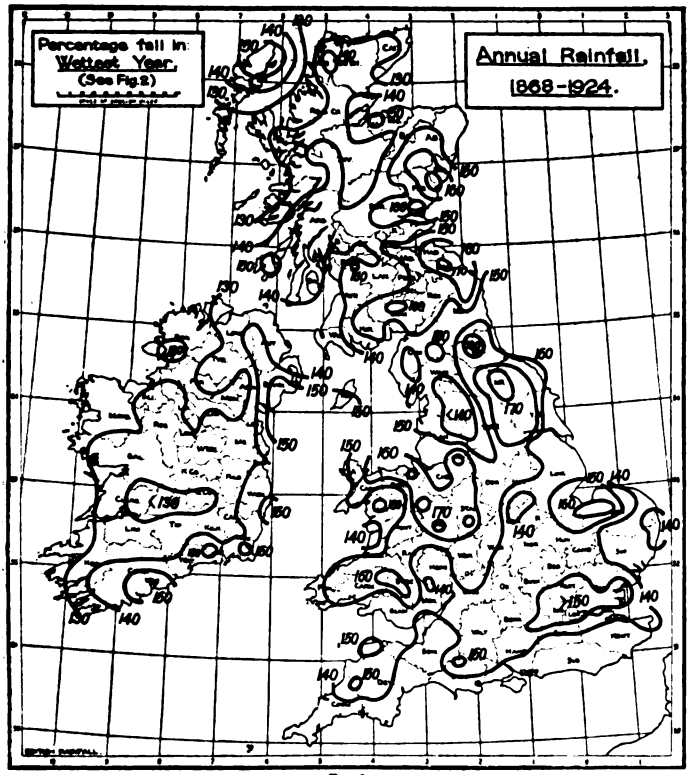

Fig. 4.

In this connection it is interesting to compare the figures of Table II. with those published by Dr. H. R. Mill[7] when working with the 30 years 1870 to 1899.

The area over which 1887 was the driest year in this period has remained very nearly the same. The dry year 1921 mainly affected the south-east of England where 1887 was not particularly dry. The addition of the 27 years has not changed the total number of years which were somewhere in the British Isles, the driest in the series. This has remained at 24.

[7] *On the Distribution of Mean and Extreme Annual Rainfall over the British Isles*, by H. R. Mill, *Proc. Inst. Civil Engin.*, **155**, Session 1903-4, part I. Maps of driest and wettest years, similar to Figs. 1 and 2, but only for the period 1870 to 1899, are given in this paper.

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TABLE I.—DETAILS OF THE AVERAGE RAINFALL, 1881 TO 1915, AND OF THE DRIEST AND WETTEST YEARS IN THE SERIES 1868 TO 1924.

County.	Station.*	Average 1881 to 1915.	Driest Year.			Wettest Year.		
			Amount.	Per cent.	Year.	Amount.	Per cent.	Year.
	England.	in.	in.			in.		
London	Greenwich (Royal Observatory)	23.50	12.56	53	1921	35.54	151	1903
,,	St. Pancras (Camden Square)	24.47	14.60	60	1921	38.10	156	1903
Surrey	Richmond (Kew Observatory)	23.80	12.16	51	1921	38.18	160	1903
,,	Haslemere (Courts Hill)	35.62	*17.45*	49	1921	49.09	138	1872
Kent	Tenterden (View Tower)	27.50	13.71	50	1921	37.81	138	1872
,,	Selling (Harefield)	30.05	*15.67*	52	1921	41.79	139	1872
,,	Edenbridge (Falconhurst)	30.71	18.27	59	1921	42.44	138	1916
Sussex	Chichester (Westgate)	28.75	17.95	62	1921	38.56	134	1894
,,	Brighton (Lewes Road)	29.94	17.61	59	1921	41.68	139	1915
,,	Crowborough (Uckfield Lodge)	36.00	24.19	67	1898	50.36	140	1872
Hampshire	Ventnor (R. National Hospital)	28.86	17.55	61	1921	39.91	138	1872
,,	Southampton (East Park)	30.93	15.97	52	1921	43.20	140	1903
,,	Sherborne, St. John Rectory	28.96	14.35	50	1921	43.41	150	1903
Berkshire	Reading (Englefield)	27.37	16.61	61	1921	40.37	147	1903
Herts	Tring (Cowroast Lock)	28.41	14.95	53	1921	42.33	149	1903
,,	Much Hadham	25.11	13.08	52	1921	37.65	150	1903
,,	Royston (Therfield Rectory)	25.19	13.08	52	1921	36.78	146	1903
Bucks	High Wycombe	25.90	15.95	62	1921	39.78	154	1903
,,	Newport Pagnell (The Croft)	23.69	14.02	59	1921	33.72	142	1875
Oxford	Oxford (Radcliffe Observatory)	24.77	14.94	60	1921	35.95	145	1903
,,	Banbury (Bodicote House)	26.32	15.91	60	1921	38.36	146	1882
Northants	Wellingborough (Swanspool)	24.27	14.00	58	1921	34.73	143	1882
Cambridge	Cambridge (Botanic Gardens)	21.92	12.13	55	1921	31.50	144	1879
,,	Stretham Engine	21.20	10.88	51	1921	31.27	148	1912
,,	Stanground Sluice	20.32	12.24	60	1921	30.61	151	1872
,,	Wisbech (Bank House)	22.99	13.62	59	1921	38.43	167	1872
Essex	Chelmsford (High Street)	22.49	14.36	64	1921	33.75	150	1903
,,	Braintree (Bocking, Fennes)	22.45	13.24	59	1921	33.40	149	1872
Suffolk	Walsham-le-Willows	25.29	14.70	58	1921	34.15	135	1912
Norfolk	Beccles (Geldeston)	23.69	11.85	50	1921	33.91	143	1872
,,	Worstead (Lyngate Cottage)	26.54	16.37	62	1921	35.54	134	1912
,,	Wells (Holkham Hall)	23.05	16.81	73	1898	32.14	139	1872
,,	Swaffham (Little Dunham)	27.19	*17.46*	64	1921	44.46	164	1872
Wiltshire	Warminster (Rye Hill)	36.91	19.18	52	1921	*52.00*	141	1872
,,	Salisbury P. (Chitterne House)	28.11	16.60	59	1921	39.27	140	1924
,,	Landford (Northlands)	30.66	16.67	54	1921	43.99	143	1915
,,	Marlborough (Mildenhall)	30.33	18.06	60	1921	43.44	143	1903
Dorset	Evershot (Melbury House)	38.66	20.86	54	1921	60.23	156	1872
Devon, S.	Launceston (Polapit Tamar)	30.25	25.13	64	1921	63.97	163	1872
,,	Ashburton (Druid House)	51.76	30.17	58	1921	71.60	138	1924
,,	Princetown (H.M. Prison)	81.87	50.69	62	1873	*115.00*	141	1882
,,	Collumpton	35.33	19.94	57	1921	47.61	135	1912
,,	Sidmouth (Sidmount)	32.41	18.37	57	1921	44.33	137	1924
,,	Lyme Regis (Pinhay)	34.87	18.65	53	1921	46.53	133	1872
Devon, N.	Filleigh (Castle Hill Gardens)	43.11	30.72	71	1921	63.80	148	1872
,,	Okehampton (Oaklands)	46.56	*33.50*	72	1921	68.37	147	1872
Cornwall	Penzance (St. Clare)	42.50	27.90	66	1887	57.21	135	1872
,,	St. Austell (Trevarna)	45.84	27.87	61	1921	62.42	136	1872
,,	Altarnon Vicarage	50.17	35.71	60	1921	84.11	142	1872
,,	Scilly (Tresco Abbey)	32.63	22.06	68	1921	44.70	137	1872
Somerset	Chew Magna	36.34	23.09	64	1921	50.84	140	1910
,,	Batheaston Reservoir	31.05	17.85	57	1870	45.77	147	1903
,,	Street (Millfield)	29.47	16.68	57	1921	40.51	137	1924
,,	Cothelstone House	34.93	19.56	56	1921	48.40	139	1872
Gloster	Quedgeley House	27.90	19.07	68	1890	42.12	151	1872
,,	Stroud (Upfield)	29.47	*17.40*	59	1921	44.31	150	1912
,,	Fairford (Kempsford)	25.62	15.47	60	1921	37.43	146	1924
Hereford	Ross (Birchlea)	28.22	17.30	61	1921	41.43	147	1872

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TABLE I.—DETAILS OF THE AVERAGE RAINFALL, 1881 TO 1915, AND OF THE DRIEST AND WETTEST YEARS IN THE SERIES 1868 TO 1924.—(*Continued.*)

County.	Station.*	Average 1881 to 1915.	Driest Year.			Wettest Year.		
			Amount.	Per cent.	Year.	Amount	Per cent.	Year.
		in.	in.			in.		
Hereford	Leominster Farm	28.41	18.87	66	1870	41.36	146	1872
Shropshire	Bishops Castle (Castle Street)	31.01	21.08	68	1921	48.96	158	1872
,,	Church Stretton (Wolstaston)	31.90	23.49	74	1887	55.24	173	1872
,,	Shifnal (Hatton Grange)	26.15	18.41	70	1921	39.49	151	1872
,,	Shifnal (Haughton Hall)	27.28	*19.60*	72	1921	44.06	162	1872
,,	Oswestry (Mount Reservoir)	34.48	22.10	64	1921	60.45	175	1872
Stafford	Market Drayton (Old Springs)	28.89	19.39	67	1921	*47.60*	165	1872
,,	Wolverhampton (Wrottesley)	25.61	*16.70*	65	1921	44.96	176	1872
Worcester	Northwick Park	28.50	*17.00*	60	1921	*43.00*	151	1912
Warwick	Rugby (Caldecott)	25.58	14.30	56	1921	36.68	143	1880
,,	Coventry (Kingswood)	27.81	*17.36*	62	1921	42.22	152	1872
,,	Birmingham (Edgbaston)	26.44	17.93	68	1921	42.16	159	1872
Leicester	Kibworth Beauchamp	25.67	18.35	71	1887	38.15	149	1872
,,	Thornton Reservoir	26.20	19.33	74	1870 1887	36.43	139	1872
,,	Belvoir Castle Gardens	25.66	16.06	63	1921	35.73	139	1882
Lincoln	Spalding (Pode Hole)	23.53	12.66	54	1921	37.12	158	1880
,,	Boston (Black Sluice, Skirbeck)	22.81	12.94	57	1887	35.53	156	1880
,,	Revesby Reservoir	24.54	15.50	63	1921	34.73	142	1883
,,	Louth (Westgate)	28.00	16.21	58	1921	*41.37*	148	1872
,,	Brigg	25.38	15.75	62	1921	36.91	145	1882
,,	Lincoln (Doddington Hall)	23.06	*15.50*	67	1921	34.48	149	1872
Nottingham	Nottingham (Strelley)	26.21	18.46	70	1887	*38.40*	146	1872
,,	Worksop (Hodsock Priory)	23.65	15.95	67	1887	*36.32*	154	1872
Derby	Mickleover (Clyde House)	26.05	15.97	61	1870	39.04	150	1872
,,	Buxton (Devonshire Hospital)	48.45	32.38	67	1887	70.35	145	1872
Cheshire	Macclesfield (West Park)	34.09	20.88	61	1887	56.12	165	1872
,,	Altrincham (Barrington House)	31.44	22.06	70	1887	54.91	175	1872
,,	Woodhead Reservoir	47.67	29.38	62	1887	65.57	138	1923
,,	Neston (Vine House)	27.36	19.97	73	1911	45.45	166	1872
Lancs, S.	Bolton (Belmont Reservoir)	56.00	*38.10*	68	1887	*80.00*	143	1877
,,	Denton Reservoir	30.46	18.57	61	1887	48.18	158	1872
Lancs, C.	Stonyhurst College	46.73	31.25	67	1887	63.92	137	1923
,,	Wigan W.W. (Worthington)	35.36	22.12	63	1887	54.84	155	1872
,,	Southport (Hesketh Park)	31.94	23.80	75	1887	48.48	152	1872
Lancs, N.	Cartmel (Holker Hall)	44.52	28.28	63	1887	63.18	142	1903
,,	Garstang (Grizedale Reservoir)	43.62	31.81	73	1887	63.24	145	1872
Yorks, W.R.	Rotherham (Moorgate Grange)	25.42	16.46	65	1921	39.26	154	1872
,,	Wath-upon-Dearne (Chapel Street)	24.80	15.07	61	1921	42.46	171	1880
,,	Goole	22.91	15.21	66	1887	38.46	168	1872
,,	Bradford (Doe Park)	40.73	27.33	67	1887	59.03	145	1872
,,	Malham Tarn	57.50	41.30	72	1887	77.12	134	1923
,,	York (Cherry Hill)	24.24	16.45	68	1887	40.38	167	1872
,,	Wetherby (Ribston Hall)	26.49	16.91	64	1893	42.70	161	1872
,,	Pateley Bridge (Castle Stead)	30.94	27.48	89	1902	61.23	153	1872
Yorks, E.R.	Pocklington (Warter)	29.03	19.10	66	1887	46.75	161	1872
,,	Patrington	23.30	16.00	69	1887 1921	33.64	144	1872
,,	Hull (Pearson Park)	25.42	16.30	64	1921	36.73	145	1872
,,	Lowthorpe (The Elms)	26.47	18.68	71	1921	36.96	140	1876
Yorks, N.R.	Leyburn (Bolton Hall)	32.63	24.00	74	1873	55.05	169	1872
,,	Osmotherley	25.80	17.89	69	1902	46.41	180	1872
,,	Malton (Broughton Rise)	25.51	19.60	77	1887	41.79	164	1872
,,	Whitby	25.08	17.78	71	1884	38.62	154	1872
Durham	Darlington (Cleveland Parade)	25.15	*18.00*	72	1873	*37.50*	149	1872
,,	Wolsingham	33.25	24.98	75	1873	53.80	162	1872
,,	Durham Observatory	24.60	18.53	75	1902	48.47	197	1872
,,	Sunderland (West Hendon House)	25.61	18.99	74	1908	36.86	144	1872

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TABLE I.—DETAILS OF THE AVERAGE RAINFALL, 1881 TO 1915, AND OF THE DRIEST AND WETTEST YEARS IN THE SERIES 1868 TO 1924.—(*Continued.*)

County.	Station.*	Average 1881 to 1915.	Driest Year.			Wettest Year.		
			Amount.	Per cent.	Year.	Amount	Percent.	Year.
		in.	in.			in.		
North'land	Newcastle (Town Moor)	27.22	20.35	75	1873	41.49	152	1872
,,	Hallington Fawcett	28.24	20.43	72	1885	40.77	144	1872
,,	Howick Hall	28.23	20.58	73	1898	41.32	146	1872
,,	Ilderton (Lilburn Tower)	27.94	18.91	68	1893	46.59	167	1872
Cumberland	Penrith (Briar Cottage)	32.77	23.53	72	1905	49.81	152	1903
,,	Carlisle (Spital Cemetery)	31.81	23.28	73	1870	47.24	149	1903
,,	Borrowdale (Seathwaite)	129.48	94.11	73	1902	*178.60*	138	1872
,,	Keswick (Derwent Island)	57.01	40.90	72	1887	77.78	136	1903
,,	Whitehaven (Irish Street)	42.27	30.58	72	1887	59.82	142	1877
West'land	Kirkby Stephen (Redman House)	42.34	28.20	67	1887	59.90	141	1894
,,	Patterdale Hall	86.40	58.87	68	1887	127.70	148	1903
,,	Appleby (Castle Bank)	35.03	24.68	70	1887	50.86	145	1903
,,	Rydal (High Close)	83.34	51.46	62	1887	123.11	148	1903
,,	Kendal	51.16	32.37	63	1887	69.18	135	1872
	Wales.							
Monmouth	Llanfrechfa Grange	42.39	*26.27*	62	1921	62.92	148	1877
,,	Abergavenny (Larchfield)	37.53	23.89	64	1921	52.20	139	1872
,,	Chepstow (Piercefield Park)	35.28	*23.55*	67	1921	57.64	164	1875
Glamorgan	Ystalyfera (Wern House)	64.83	43.48	67	1889	91.30	141	1872
,,	Glyncorrwg	85.42	59.86	70	1889	117.57	138	1872
,,	Cowbridge (Fonmon Castle)	36.77	23.98	65	1887	*52.80*	144	1882
,,	Cardiff (Ely Pumping Station)	42.12	27.08	64	1921	56.73	135	1882
,,	Aberdare (Mardy)	60.45	42.04	69	1889	96.61	160	1872
Carmarthen	Carmarthen (The Friary)	48.30	33.82	70	1887	76.20	158	1872
Pembroke	Castle Malgwyn	43.78	29.33	67	1887	68.26	156	1872
,,	Haverfordwest (Grammar School)	46.37	35.23	76	1887	69.78	150	1872
Cardigan	Aberystwyth (Gogerddan)	46.49	34.49	74	1887	62.82	135	1923
Radnor	Birmingham W.W. (Nantgwilt)	63.24	45.41	72	1892	97.70	154	1872
Mont.	Newtown (Penarth Weir)	34.99	25.37	72	1921	67.73	194	1872
Flint	Bodfari (Nantlys)	27.42	21.17	77	1921	47.82	174	1872
Denbigh	Wrexham (Packsaddle Reservoir)	32.00	23.47	73	1921	52.80	165	1872
Merioneth	Bala (Eryl Aran)	54.61	38.94	71	1887	78.99	145	1903
,,	Landerfel (Palé Gardens)	48.19	37.37	78	1887	70.44	146	1903
,,	Corwen (Rûg Gardens)	36.18	28.51	79	1894	49.85	138	1877
,,	Blaenau Festiniog (Oakley Q.)	97.14	69.81	72	1902	142.65	147	1918
,,	Dolgelly (Bryntirion)	58.79	*39.50*	67	1887	90.13	153	1923
Carnarvon	Llandudno	30.04	21.61	72	1887	48.02	160	1872
,,	Carnarvon (Belan Fort)	33.94	24.54	72	1887	*51.10*	151	1872
,,	Llanfairfechan	37.90	28.72	76	1887	66.03	174	1872
,,	Criccieth (Talarvor)	36.58	23.55	64	1873	55.31	151	1877
Anglesey	Llanerchymedd (Llwydiarth Esgob)	38.10	27.98	73	1887	*58.74*	154	1872
I. of Man	Douglas (Borough Cemetery)	41.19	26.98	65	1887	62.94	153	1872
	Scotland.							
Kirk'bright	Gatehouse (Cally)	48.97	36.12	74	1878	70.57	144	1877
,,	Auchencairn (Torr House)	47.05	34.10	72	1880	70.55	150	1877
,,	Dumfries (Cargen)	44.77	30.77	69	1880	63.50	142	1872
Dumfries	Moffatt (Craigielands)	52.35	37.18	71	1887	86.00	164	1872
,,	Canonbie (Byreburnfoot)	42.05	30.62	73	1902	64.25	153	1877
Roxburgh	Hawick (Wolfelee)	37.61	24.98	66	1905	57.04	152	1872
,,	Kelso (Springwood Park)	26.19	*18.36*	70	1902	38.91	149	1916
Selkirk	Selkirk (The Hangingshaw)	34.79	25.39	73	1905	*59.50*	171	1872
,,	Galashiels (Abbotsford Road)	31.75	24.29	77	1902	49.02	154	1872
Berwick	Marchmont House	32.25	24.38	76	1902	55.20	171	1872
,,	West Foulden	25.46	19.24	76	1898	*41.30*	162	1872
Midlothian	Pentland Hills (Glencorse Filters)	38.56	27.70	72	1870	59.40	154	1916
,,	Edinburgh (Charlotte Square)	25.12	17.95	71	1885	39.25	156	1916

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TABLE I.—DETAILS OF THE AVERAGE RAINFALL, 1881 TO 1915, AND OF THE DRIEST AND WETTEST YEARS IN THE SERIES 1868 TO 1924.—(*Continued.*)

County.	Station.*	Average 1881 to 1915.	Driest Year.			Wettest Year.		
			Amount	Per cent.	Year.	Amount	Per cent.	Year.
		in.	in.			in.		
Lanark	Airdrie (Hillend Reservoir)	37.32	24.13	65	1870	*51.00*	137	1872
Ayr	Girvan (Pinmore)	49.84	39.42	79	1895	67.66	136	1877
Renfrew	Gorbals Dist. W.W. (Waulk Glen)	47.16	33.35	71	1870	71.25	151	1903
,,	Shaws W.W. (Loch Thom)	65.36	48.49	74	1895	90.03	138	1877
Dumbarton	Helensburgh W.W.	48.80	35.82	73	1870	72.72	149	1872
Stirling	Falkirk (Kerse)	31.85	21.50	68	1870	49.43	155	1903
,,	Strathblane (Mugdock Reservoir)	46.16	31.60	68	1902	63.60	138	1872
Bute	Rothesay (Crichton Road)	51.60	*35.00*	68	1870	*72.00*	140	1923
Argyll	Mull of Kintyre	41.10	25.77	63	1889	66.90	163	1872
,,	Islay (Eallabus)	48.86	38.78	79	1887	75.82	155	1923
,,	Lismore (Mousedale)	43.71	29.92	68	1875	63.23	145	1877
,,	Mull (Quinish)	56.75	44.04	78	1895	*69.74*	123	1923
Kinross	Loch Leven Sluice	35.77	23.20	65	1870	52.19	146	1903
Perth	Loch Dh.	79.77	57.00	71	1887	118.70	149	1903
,,	Loch Vennachar	55.29	39.10	71	1870	79.30	143	1877
,,	Glengyle	89.90	65.90	73	1902	129.50	144	1903
,,	Balquhidder (Stronvar)	74.24	53.24	72	1889	109.02	147	1903
,,	Crieff (Strathearn Hydro)	40.88	28.78	70	1919	63.47	155	1872
,,	Perth (Wellshill Cemetery)	30.71	20.14	66	1870	47.56	155	1916
,,	Dalnaspidal	*61.96*	47.00	76	1871	81.34	131	1877
Forfar	Kirriemuir (Lintrathen)	34.67	23.25	67	1887	48.49	140	1877
,,	Dundee (Eastern Necropolis)	27.42	17.08	62	1911	44.55	162	1876
,,	Montrose (Sunnyside Asylum)	27.03	18.45	68	1921	46.44	172	1872
Kincardine	Fettercairn (Police Station)	33.02	19.78	60	1921	57.70	175	1872
Aberdeen	Braemar (Bank)	35.38	25.00	71	1904	59.25	167	1872
,,	Aberdeen (Cranford House)	31.74	18.86	59	1921	*44.80*	141	1872
,,	Ellon (Esslemont House)	29.78	19.47	65	1921	44.36	149	1872
,,	New Deer School	32.34	21.36	66	1921	47.51	147	1872
Banff	Keith Station	33.79	25.50	75	1870	48.98	145	1915
Moray	Gordon Castle	29.77	22.04	74	1913	43.67	147	1872
,,	Grantown-on-Spey	31.15	22.72	73	1913	42.63	137	1872
Nairn	Cawdor (Budgate)	28.95	21.16	73	1870	46.34	160	1916
Inverness	Alvie Manse	30.28	24.34	80	1887	*41.13*	136	1916
,,	Loch Quoich (Glenquoich)	110.75	84.53	76	1869	157.71	142	1874
,,	Inverness (High School)	27.09	19.51	72	1887	*39.30*	145	1877
,,	Loch Shiel (Glenfinnan)	107.98	83.60	77	1895	144.74	134	1868
,,	Fort William (Atholl Bank)	78.80	54.62	69	1915	108.18	137	1877
Ross	Alness (Ardross Castle)	38.54	26.97	70	1887	54.20	141	1903
,,	Fearn (Lower Pitkerrie)	22.43	16.61	74	1897	32.19	143	1877
,,	Applecross Gardens	57.28	42.99	75	1887	74.64	130	1923
,,	Stornoway	49.85	33.68	68	1880	76.80	154	1872
Sutherland	Dunrobin Castle	31.69	24.27	77	1897	41.65	131	1877
Caithness	Wick	29.92	18.91	63	1871	38.63	129	1923
Orkney	Shapinsay (Balfour Castle)	31.98	24.18	76	1902	*48.15*	151	1898
	Ireland.							
Cork	Cork (University College)	39.97	26.45	66	1887	61.57	154	1872
Kerry	Darrynane Abbey	51.02	34.88	68	1901	67.02	131	1872
,,	Valencia (Glanleam)	56.97	43.00	75	1887	...	...	...
Waterford	Waterford (Brook Lodge)	39.47	23.33	59	1887	...	...	...
,,	Portlaw (Mayfield)	43.10	26.66	62	1887	65.85	153	1903
,,	Clonmel (Glenam)	41.74	27.34	66	1887	59.13	142	1872
Tipperary	Nenagh (Castle Lough)	39.52	29.11	74	1887	50.31	127	1918
Clare	Miltown Malbay	45.70	32.26	71	1902	*60.79*	133	1897
Wexford	Faulkesmill (Longraigue)	39.32	24.95	63	1887	61.59	157	1872
,,	Enniscorthy (Ballyhyland)	42.75	27.33	64	1887	57.25	134	1872
,,	Gorey (Courtown House)	34.07	22.91	66	1887	52.10	150	1872
Carlow	Bagnalstown (Fenagh House)	34.95	21.50	62	1887	51.92	149	1872

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TABLE I.—DETAILS OF THE AVERAGE RAINFALL, 1881 TO 1915, AND OF THE DRIEST AND WETTEST YEARS IN THE SERIES 1868 TO 1924.—(*Continued.*)

County.	Station *	Average 1881 to 1915.	Driest Year.			Wettest Year.		
			Amount.	Per cent.	Year.	Amount	Per cent.	Year.
		in.	in.			in.		
Carlow -	Carlow (Browne's Hill) - -	34.15	22.49	66	1887	47.29	138	1872
Queen's Co.	Abbey Leix (Blandsfort) - -	36.55	24.59	67	1887	47.03	129	1903
King's Co.	Birr Castle - - - - -	32.69	23.47	72	1887	42.76	131	1924
Dublin -	Dublin (Fitzwilliam Square) - -	27.37	16.60	61	1887	38.61	141	1916
,, -	Balbriggan (Ardgillan) - - -	28.96	20.43	71	1887	43.26	149	1872
Westmeath -	Athlone (Twyford) - - - -	37.00	27.10	73	1905	51.10	138	1877
,, -	Mullingar (Belvedere) - - -	36.34	25.43	70	1887	48.28	133	1903
Louth -	Greenore - - - - -	31.91	22.91	72	1887	...	...	...
Galway -	Ballinasloe - - - - -	36.71	26.61	73	1887	47.92	130	1900
,, -	Ahascragh (Clonbrock) - - -	41.56	30.39	73	1887	57.90	139	1913
Mayo -	Crossmolina (Enniscoe) - - -	53.27	46.13	87	1887	68.59	129	1923
,, -	Ballinrobe (Cranmore) - - -	48.68	*33.70*	69	1875	63.14	130	1924
Sligo -	Collooney (Markree Observatory) -	43.53	36.20	83	1893	59.26	136	1924
Cavan -	Belturbet (Cloverhill) - - -	34.63	24.50	71	1887	44.71	129	1877
Armagh -	Armagh Observatory - - -	31.75	22.29	70	1870	39.66	125	1872
Down -	Seaforde - - - - -	38.29	24.66	64	1887	57.57	150	1872
,, -	Banbridge (Milltown) - - -	30.99	23.08	74	1887	46.60	150	1872
Antrim -	Belfast (Queen's University) -	34.61	23.45	68	1887	45.42	131	1923
Derry -	Garvagh (Moneydig) - - -	38.83	30.28	78	1887	55.00	142	1872
,, -	Limavady (Drenagh) - - -	36.99	28.71	78	1911	48.52	131	1877
Tyrone -	Omagh (Edenfel) - - - -	40.12	30.82	77	1885	54.86	137	1903
Donegal -	Buncrana (Rockfort) - - -	41.02	33.18	81	1885	53.29	130	1877
,, -	Convoy House - - - -	46.59	36.98	79	1897	59.15	127	1916

Values in italics have been partly computed.

* The latitude and longitude of each station is given in *The Book of Normals*, M.O. 236, Sec. V. The order of the stations is that given in *British Rainfall*.

TABLE II.—PROPORTION OF BRITISH ISLES OVER WHICH CERTAIN YEARS WERE THE DRIEST IN THE SERIES, 1868 TO 1924.

1870.	1880.	1887.	1893.	1895.	1902.	1921.	17 other years.	Total.
8	2	40	2	3	3	31	11	100

TABLE III.—PROPORTION OF BRITISH ISLES OVER WHICH CERTAIN YEARS WERE THE DRIEST IN THE SERIES, 1870 TO 1899.

1870.	1874.	1887.	1893.	1898.	19 other years.	Total.
18	4	41	7	6	24	100

Details of the rainfall of certain dry years were given in a paper read before this Society in 1922,[8] and these need not, therefore, be dealt with here. The series of annual maps also gives more detailed information.[6] The map, Fig. 3, showing the percentage fall in the driest year, may be considered to be composed of a number

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of pieces of the series of annual maps referred to above, the particular pieces selected being indicated in Fig. 1. The distribution of rainfall shown in Fig. 3 is mainly, therefore, that of the dry years 1887 and 1921.

The Wettest Years over the British Isles.

From the map, Fig. 2, the extents of the area, over which certain years were the wettest in the series, were determined. The result is set out in Table IV. The year 1872 is even more remarkable than the dry year 1887 in affecting as much as 49 per cent. of the total area of the British Isles compared with 40 per cent. in the case of 1887. It is noticeable that the distribution shown in Fig. 4 is very like that of the wet year 1872. Of the 57 years

Table IV.—Proportion of the British Isles over which certain years were the wettest in the series, 1868 to 1924.

1872.	1877.	1882.	1903.	1912.	1916.	1923.	1924.	14 other years.	Total.
49	9	1	19	2	2	8	5	5	100

as many as 22 were the wettest in some part of the British Isles. Of these, 14 years each affected less than 1 per cent. of the total area of the British Isles, the remaining eight years accounting for 95 per cent. of the whole area. The area affected by 1872 was most widespread in England and in Wales where as much as 63 and 75 per cent. respectively of the total areas was concerned. For Scotland and Ireland the corresponding figures were 37 and 34 per cent. The years 1877 and 1923 were the wettest over 23 per cent. and 17 per cent. respectively of Scotland; 1903 affected as much as 31 per cent. and 1924 about 14 per cent. of Ireland.

The figures previously published by Dr. H. R. Mill are set out below for comparison:—

Table V.—Proportion of the British Isles over which certain years were the driest in the series, 1870 to 1899.

1872.	1877.	1882.	1899.	15 other years.	Total.
65	15	6	2	12	100

So that annual totals for more recent years have in many places exceeded the standard set by 1872 and the falls of 1923, 1924 and more especially 1903 now rank as the largest on record. It is a most striking fact that falls which were recorded in 1872, *i.e.*, 53 years ago, have not yet been exceeded over areas covering practically half the British Isles.

* "The Drought of 1921," by C. E. P. Brooks and J. Glasspoole, *Q.J.R. Meteor. Soc.*, **45**, 1922, p. 141.

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It may be that a particular year is the driest in the series in one part of the British Isles and the wettest in another part. This happened in four years, viz., 1875, 1880, 1897 and 1915. In each case the areas concerned were less than 2 per cent. of the whole area. It is interesting to note that of the 57 years as many as 42 were the driest or wettest at some one or more stations in the British Isles.

General Means of Extremes (Figs. 3 and 4).

The means of the percentage values given on the maps, Figs. 3 and 4, showing the falls of the driest and wettest years for the British Isles, were determined by taking a series of 100 points equally distributed over the British Isles, tabulating the figures from the map and taking the means. In some cases the values were estimated from the maps. The results are set out below together with the general values calculated for the extreme years 1887 and 1872.

Table VI.—General Means evaluated from Figs. 3 and 4.

	Driest Year.		Wettest Year	
	Fig. 3.	1887.	Fig. 4.	1872.
1	2	3	4	5
	%	%	%	%
England and Wales .	64	74	148	144
Scotland . . .	72	80	144	134
Ireland	72	77	136	128
British Isles . . .	68	77	145	137

The figures given in columns 2 and 4 may be taken as extreme values, which are not likely to be surpassed in any one dry or wet year. The difference between the two sets of figures is least in columns 4 and 5 for England and Wales owing to the fact that 1872 was the wettest year over as much as 64 per cent. of the whole area.

The present paper was prepared in answer to the question which is often asked as to what are the extremes of annual rainfall which have occurred at some particular place in the British Isles. Reference to the four maps gives answer readily, the only qualifications being (*a*) that the answer covers the period 1868 to 1924, (*b*) that the answer depends on the distribution of stations, and (*c*) the answer is obtained as a percentage of the average fall. Reference to Table I. gives the actual figures at the nearest stations.

DISCUSSION.

Mr. L. C. W. Bonacina asked if Dr. Glasspoole would follow up this paper by a similar paper dealing with the number of wet days, because it is that which makes a climate. He had been particularly interested in frequency of late. If annual distribution of rain-days in

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these islands is examined, it is found that the differences are not proportional to the differences in the annual amounts. Everywhere in the British Isles frequency of rain was high—a fact which tended to impart a character of raininess even to the drier parts. With regard to the point mentioned in the paper that some years were the driest in one part of the British Isles and the wettest elsewhere, he had always maintained that the British Isles, taken together, were not nearly such a good climatological unit as were England, Scotland and Ireland separately, and he regretted the common practice of lumping the three kingdoms together.

Mr. R. H. HOOKER said that it looked to him as if the dry side where the rainfall was steady would show the greatest variation. It does not follow that actual extremes expressed in inches of rainfall are greater in the dry side than in the wet, but he fully expected to find it so. He would like to know, if Dr. Glasspoole could tell them, which were the driest and wettest years over a longer period.

The PRESIDENT (Sir Gilbert Walker) said in relation to a point raised that in India that if you took a wet year and a dry year and divided in each case the year's rainfall by the number of wet days, you would find that the average amount of rainfall on a wet day for the wet year was practically the same as for the dry year: thus it is the number of days that are wet in the year which decides the rainfall. He, further, remarked that the English charts in some respects recalled those of India where the regions with the largest variability of rainfall are not those with a large normal supply; it is in desert areas where you have an annual rainfall of six inches that you are specially liable to a thunderstorm of ten inches which will give you your year's supply in a few hours. There was some indication of that in the English chart of percentages for the driest years in that the regions furthest from the west coast show the greatest variations.

Dr. GLASSPOOLE, in reply, said that in connection with the question of the variability of rainfall, as a percentage of the average, he had dealt with the subject in *British Rainfall*, 1921, in a paper on "Fluctuations of Annual Rainfall," in which the mean deviation of annual rainfall had been worked out for 35 years for a number of stations over the British Isles, and also in a paper in *British Rainfall*, 1922, on "Fluctuations of Monthly Rainfall," in which the mean deviation of the falls in the successive Januarys and Julys in the 35 years had been computed. From these papers it appeared that while in general the wettest stations did experience a smaller percentage variability of rainfall, the controlling feature was "continentality." Thus the areas with the largest percentage variability were not in the driest areas of the British Isles, viz., along the east coast of Great Britain and of Ireland, but rather in the central regions of the land masses, especially in the Midlands and South of England.

With reference to Mr. Hooker's remarks, it was possible to extend the records back at only a few stations, chiefly in England, and this would have left the greater part of Ireland and the north-west of Scotland unrepresented. Neither could such records as were available always be regarded as homogeneous with more recent records.

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On the Random Sequence.

In an interesting note, E. G. Bilham points out that quite apart from the use of correlation coefficients, the trend of a random sequence of values will change sign on the average twice in three trials. In fact, of three unequal values, one is greater than both the others, one is less than both the others, and the third is neither; one or other of these must come second in order, and if the greatest or the least comes second, the successive differences will be of opposite signs.

Mr. Bilham adds: "By reasoning on generally similar lines, it may be shown that if n successive differences have similar signs, the chances are $n+1$ to one in favour of a change of sign in the next difference." The *caveat* should, perhaps, be added that both rules depend absolutely upon ignoring the changes previous to the sequence used for prediction, as well as on ignoring the actual deviation observed from the mean of the series.

A more general view is to consider the frequency with which a "run" of increasing or decreasing values is of 1, 2, 3, . . . differences; in fact, to determine the frequency distribution of length of run. The frequency of a run of n successive increases or decreases is then found to be

$$3\left\{\frac{1}{(n+1)!}-\frac{2}{(n+2)!}+\frac{1}{(n+3)!}\right\}$$

corresponding to the series of fractions

$$\frac{5}{8},\ \frac{11}{40},\ \frac{19}{242},\ \frac{29}{1{,}680},\ \frac{41}{13{,}440},\ \frac{55}{120{,}263},\ \frac{71}{1{,}209{,}600},\ \ldots$$

If, therefore, a run of one increase only has been observed, the chance that it will be followed by a decrease is $\frac{5}{8}$ and not $\frac{2}{3}$, the latter probability being correct when the last change is known to be an increase, but whether preceded by an increase or a decrease is unknown.

The probability of a run of n or more is evidently

$$3\left\{\frac{1}{(n+1)!}-\frac{1}{(n+2)!}\right\}$$

and consequently when such a run has been observed, the probability of a change is

$$\frac{n^2+3n+1}{(n+1)(n+3)}=1-\frac{(n+1)(n+3)}{n+2}$$

The extreme rarity of runs of 5, 6 or 7 differences is of value in the use of such runs as evidence that a sequence is in parts not of a random character; such a test may be refined by counting all the runs of all lengths and comparing the frequency of each class observed with that predicted by the above distribution.

The mean of the distribution is, of course, $1\frac{1}{2}$; but the other moment functions involve e and powers of e; thus the variance is $6(e-2\frac{5}{8})=.5597$, and the third moment about the mean is $45(41/15-e)=.6773$.

R. A. FISHER.

Rothamsted Experimental Station.
July 5, 1926.

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THE METEOROLOGICAL CONDITIONS DURING THE GLACIATION OF THE PRESENT TROPICS, BEING SOME REMARKS ON THE CLIMATOLOGICAL BASIS OF WEGENER'S THEORY OF CONTINENTAL DRIFT.

By C. E. P. BROOKS, M.Sc.

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Everyone nowadays has heard of Wegener's theory of continental drift, according to which the present scattered continents were, during a large part of geological time, grouped as a single gigantic land-mass or Pangæa, which later split up, the constituent parts drifting mainly to the west and north. The actual movements postulated by Wegener are of two different kinds, an east-west movement due to tidal forces, and a "flight from the poles" which is common to all floating bodies on the earth's surface. These two forces are entirely independent; the east-west tidal force is somewhat indefinite but may be large, the other force is known to be small. The evidence that the continents have actually moved under the action of these two forces is also of different nature in the two cases. The east-west movements are supported by some stratigraphical and biogeographical evidence, and the east-west separation of America from Eurafrica at least is probably justified. On the other hand the south-north movements of much greater amplitude rest almost entirely on palæoclimatological evidence, and especially on the distribution of the climatological zones during the Permo-Carboniferous period. This period was characterized by a great development of inland ice-sheets in Australia, India, Central and Southern Africa and South America, while at the same time a rich vegetation flourished in the present temperate latitudes of Asia, Europe and eastern North America. Wegener therefore places the south pole during this period in the neighbourhood of South Africa and draws the equator through the coal-measure belt, which in his opinion was equivalent to the present tropical rain forest belt.

If there were no glacial deposits in the Permo-Carboniferous other than those in the southern hemisphere already alluded to, I think that in the present state of our geological knowledge Wegener's theory would be the most satisfactory solution. Deposits doubtfully attributed to glacial action have been known in Europe for many years, but they are very scrappy, and Wegener had no difficulty in sweeping them aside. The glacial deposits of the United States, however, are a more serious obstacle to Wegener's theory, and recent work in that country has tended to strengthen the probability that there was a considerable amount of ice even at sea level, and of floating ice in the sea. Before proceeding to a discussion of the meteorological conditions of that period, therefore, it is necessary to run briefly over this evidence.

S. Weidmann[1] describes conglomerates of Upper Carboniferous to Permian age in the Arbuckle and Wichita Mountains of Oklahoma

[1] Weidmann, S., "Was there a Pennsylvanian-Permian glaciation in the Arbuckle and Wichita mountains of Oklahoma?" *Chicago, J. Geol.*, **31**, 1923, p. 466.

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and Kansas, associated with all the paraphernalia of glaciation—scratched boulders, erratics, fluted and polished floors, and U-shaped valleys. Some of the boulders in marine deposits have apparently been carried by icebergs, and the author attributes the phenomena to islands in the late-Palæozoic sea bearing local valley glaciers. J. A. Taff and E. O. Ulrich[2] found boulders up to 20 feet across and five or six feet thick, fifty miles or more from their source, in the marine Caney shales of eastern Oklahoma. "No other competent means of their transportation than ice—presumably heavy shore ice—has been suggested." These shales were examined by an impartial observer, J. B. Woodworth,[3] who concluded that while the striæ on the boulders which he observed were probably not glacial, the transport of the boulders was almost certainly effected by floating ice. Further west, in Colorado[4] there were Middie Carboniferous conglomerates some 6,000 feet in thickness, said to contain boulders up to 50 feet in diameter, and although no striated boulders have yet been found, the great size of the boulders strongly suggests ice-action.

The most remarkable deposits in the United States are the Squantum Tillites near Boston, Mass., massive conglomerates 2,000 feet in thickness which cover a considerable area. The chief interest of these beds, apart from the presence of striated boulders, lies in the associated "varve" beds[5]—banded clays which are similar in all respects to those formed during the retreat of the Scandinavian and North American ice-sheets at the close of the Pleistocene glaciation. These clays owe their banding to the seasonal variations in the rate of melting of glaciers, and are therefore incompatible with an equatorial climate. In places the banding was disturbed during the deposition of the shales, probably by the grounding of floating ice-masses. A. P. Coleman, summing up in 1925, considered that there is good evidence for glaciation in Oklahoma, Nova Scotia and Alaska (Thousand Isles). As regards Nova Scotia, he writes:[6] "It is . . . probable that there were moderate elevations from which, under a cool climate, glaciers spread out over the plains on which coal forests had been growing not long before."

Wegener[7] dismisses these American deposits rather briefly:

> "The description which Sayles gives [of the Squantum Tillite] appears very convincing; he pictures scratched boulders and gives the localities, which cover a considerable area. Smoothed rocks under the moraines have not yet been determined, so that we are only dealing with phenomena which can arise with deceptive similarity in non-glacial ways. Perhaps great elevation may account for this Squantum Tillite . . . but

[2] Taff, J. A., and Ulrich, E. O., "Ice-borne boulder deposits in Mid-Carboniferous shales." *Bull. Geol. Soc. America*, **20**, 1908, p. 701.

[3] Woodworth, J. B., "Boulder beds of the Caney shales at Talihina, Oklahama." *Bull. Geol. Soc. America*, **23**, 1912, p. 457.

[4] Sussmilch, C. A., and T. W. E. David, "Sequence, glaciation and correlation of the Carboniferous rocks of the Hunter River district, New South Wales." *Sydney, J. R. Soc. New South Wales*, **53**, 1919, p. 246.

[5] Sayles, R. W., "Seasonal deposition in aqueoglacial sediments." *Cambridge, Mass., Mem. Mus. Comp. Zool.*, **47**, 1919, No. 1.

[6] Coleman, A. P., "Late Palæozoic climates." *Amer. J. Sci.*, **9**, 1925, p. 195.

[7] Köppen, Wladimir, und Wegener, Alfred, "Die Klimate der geologischen Vorzeit," Berlin, 1924, p. 33.

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> the preservation of such high-level moraines is little probable, for deposits formed at a great height are as a rule destroyed by erosion. As all the other climatic evidence . . . clearly shows that Boston in the Carboniferous lay in the equatorial rain belt, in the Permian in the region of the hot deserts, *the glacial nature of these tillites is in irreconcilable opposition to the numerous climatic traces of another kind which surround it both in space and time. . .*"

Wegener cites only one reference to the glacial deposits in the United States, which dates from as long ago as 1914, so that he was apparently not acquainted with the recent literature.

But if there be little doubt that glaciers reached sea-level near Wegener's equator, and no doubt at all that glaciers reached sea-level near the present equator, what is the poor meteorologist to do? His natural instincts tell him that extensive glaciation along the equator is impossible. One thing it seems he must do; he must re-examine his natural instincts in connection with the geographical conditions of the Upper Carboniferous. That is the purpose of this paper.

The science of palæogeography is at present in a state of flux, owing to the general recognition of the distinction between the sial of the continents and the sima of the ocean floors. Till some finality has been reached, however, it seems best to adhere to the reconstructions based on the present position of the continents, and that given by Th. Arldt[8] in the best and most recent of the text-books of palæogeography has been employed as a basis. It should be remarked that the safest of Wegener's deductions, the rapprochement of America and Eurafrica, would make little difference to the discussion which follows.

Fig. 1, then, gives a reconstruction of the geography of the Upper Carboniferous. In the northern hemisphere we find three small continents: Nearctis, a primitive North American continent; North Atlantis, including Greenland and Western Europe; and Angaraland occupying part of the present Siberia. Nearctis and North Atlantis were connected by a land-bridge in about 50°N. South of these three continents a mighty Central Sea (Tethys, the forerunner of the Mediterranean) extended nearly east and west from New Guinea to Central America, sending an arm between North Atlantis and Angaraland northward to the Arctic Ocean. This Central Sea was bounded on the south by the great continent of Gondwanaland, extending in a huge crescent from South America to Australia, and from 20°N. to 40°S.

The Carboniferous was a period of great mountain-building, the main ranges running either north-south or east-west. A range followed the south coast of North Atlantis into the Mediterranean region. The site of the Alps was occupied by the Carnic Range and there were other ranges in the Caucasus and the Dobrudja. In the west the Pyrenees and Asturia were mountainous. Further north a range or a series of ranges ran from Bohemia first northward through the Sudetes and then westward through Germany. In the west we have the Armorican chain through Brittany, South England, Wales, South Ireland and beyond into North Atlantis. In Nearctis

[8] Arldt, Th., "Handbuch der Palæogeographie." Leipzig, 1919.

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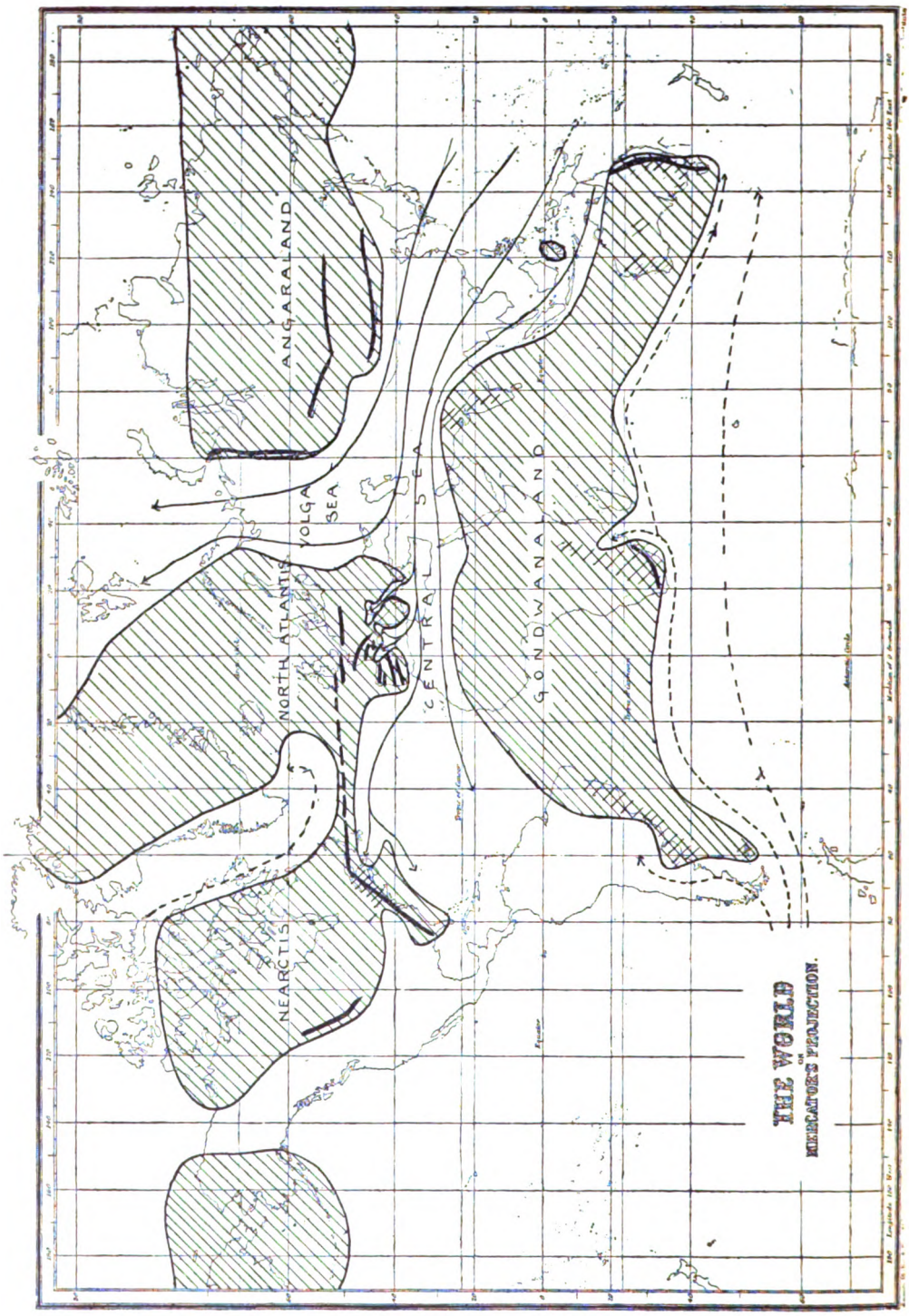

FIG. 1.—Geography and Ocean Currents of Permo-Carboniferous.

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the Appalachians were rising, turning westward in the south to the mountains of Oklahoma and South Arkansas. Other ranges formed the west coast of Nearctis, from Colorado northwards. In Asia there were a number of east-west ranges somewhat similar to the present systems, bounded on the west by the Urals and the Volga Sea, on the south by the Central Sea. The mighty continent of Gondwanaland was bounded on the west by the Proto-Cordilleras and the mountains of the Pampas, extending to the Falkland Islands. In the south of Africa there was another chain, and a great range ran along the whole eastern coast of Australia and the present East Indies. These mountain systems are shown by the heavy lines in the figure. Between the mountain ranges in the northern hemisphere there were for the most part wide moist valleys open to the sea, the home of a rich vegetation.

Over the main area of Gondwanaland conditions appear to have been different from those of the northern continents. In India, for example, a plateau formed of the Vindhyan sandstone extended over a great area, probably rising gradually northwards to an elevation of many thousand feet. The country was not mountainous; the whole region was lifted bodily with little disturbance. The height of a large part of this plateau may have been as great as that of the Tibetan plateau at present, but unlike the latter it was not shut in by bounding mountains. Similar high-level plateaus may have existed over a great part of Gondwanaland, but as such movements of simple uplift leave few traces, they are difficult to recognize. The enormous thickness of the Permo-Carboniferous beds of South Africa, however, points to rapid denudation, suggesting a large area of high ground in the interior of that continent. We may therefore take as a working hypothesis a great plateau in the interior of Gondwanaland, rising gradually to a height of 10,000 or 15,000 feet in the north.

Finally, it has to be remarked that the Permo-Carboniferous was a period of intense volcanic activity, and especially in Australia great thicknesses of agglomerates point to numerous explosive eruptions from which we may infer the presence of great quantities of volcanic dust in the atmosphere, forming a veil which, as Humphreys[9] has shown, was very effective in shutting out the solar radiation, while it allowed the terrestrial radiation to escape with little hindrance.

We can now attempt to reconstruct the distribution of the meteorological elements. Over the open Pacific Ocean there is no reason to suppose that the distribution of pressure and winds was appreciably different from that prevailing now, though owing to the volcanic dust veil the temperatures may have been somewhat lower. Hence we postulate a great equatorial current setting westward towards the eastern coast of Gondwanaland, with a temperature of nearly 80°F. The configuration of the eastern coast of this continent appears to have been very favourable for concentrating this current and directing it into the Central Sea, more favourable even than the present configuration of the coast of America for concentrating the Equatorial Currents of the Atlantic in the Gulf Stream. This must have raised the temperature of the whole northern hemisphere at

[9] Humphreys, W. J., "Physics of the Air," Philadelphia, 1920.

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the expense of that of the southern hemisphere. A very warm current with a temperature approaching 80°F. must have flowed through the narrow intercontinental Central Sea, the supply of warm water being large enough to give this current a considerable velocity, perhaps fifty miles a day, enabling it to conserve its heat over a long distance. Part of this warm current turned northward through the Volga Sea and brought favourable conditions to northern Russia, where the Fusulinæ appear to indicate a temperature as high as that now found in the Mediterranean,[10] and to Spitsbergen and neighbouring parts of the Arctic Ocean. The remainder of the warm equatorial current travelled on between the Americas and finally emerged again into the Pacific Ocean. Evidently there is no difficulty in accounting for the rich corals of the Central and Volga Seas or the rich vegetation of the valleys opening off them.

In the Southern Ocean also, between the horns of the great crescent of Gondwanaland, it seems probable that the surface temperatures did not differ greatly from those prevailing at present in the same latitudes of the South Indian Ocean. The absence of the great masses of floating ice derived from the Antarctic would have tended to raise the temperature of the whole ocean, but on the other hand the Southern Ocean was limited in the north by land in the neighbourhood of 40° instead of extending to the equator, and the absence of the supply of equatorial warm water would tend to balance the absence of the supply of ice. We have also to take into account the volcanic dust veil. At present the mean temperature of the ocean surfaces in latitude 40-50° is about 50°F., and we shall probably not be far out if we take the same figure for the temperature of the surface water south of Gondwanaland.

The "planetary" circulation of the atmosphere requires a belt of low pressure over the equatorial regions, a series of anticyclones in about latitudes 30-40°, followed by belts of low pressure and storms in temperate or sub-polar latitudes. This system is modified by the land and sea distribution, which gives a tendency for high pressure over the land in winter and over the sea in summer. The geographical disturbance of the planetary circulation is so great over Asia that the anticyclonic centre there does not develop at all in summer, while in winter it attains a great intensity and is displaced some distance north of 30°N. The deflection of the entire Equatorial Current northwards into the Central Sea would probably suffice to maintain the temperature of middle latitudes north of Gondwanaland permanently above that of middle latitudes south of Gondwanaland, introducing an effect of permanent summer in the northern hemisphere and permanent winter in the southern hemisphere. We should expect to find a permanent low pressure area over the Central Sea and the Volga Sea, while the normal sub-tropical anticyclone was developed off the southern coast of Gondwanaland.

This brings me to the first of the three meteorological problems associated with the Permo-Carboniferous: under the conditions postulated, with an area of high pressure to the south of the equator separated by a very long and lofty plateau from an area of low

[10] Staff, H. v., "Zur Entwicklung der Fusuliniden." *Zentralbl. f. Min., Geol. und Pal.*, 1908, p. 699.

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pressure to the north of the equator, what would be the wind system over the plateau? We have no close parallel at present for guidance; the nearest approach is found over Asia and the Indian Ocean during the south-west monsoon, but most of India is now at a comparatively low level, and the highest temperature and lowest pressure are found near Jacobabad to the south of the Himalayan ridge. A large portion of the air which enters India from the high pressure area to the south is accordingly deflected to flow westward parallel with the mountain barrier; it is only in the north-east that the air crosses at least the Khasi Hills (giving the enormous rainfall of Cherrapunji), and possibly the main ridge of the Himalayas. If the area of lowest pressure were north of the latter range, would the stream lines run directly across it?

The power of air currents to cross high ridges of land probably depends to a large extent on the steepness of the slope. The west-south-west winds from the Arabian Sea are able to cross the Western Ghats, for the greater part of their length more than 4,000 feet in height,[11] and descend on the other side as a dry wind. The obstacle presented by the Himalayas, exceeding 12,000 feet, may be due quite as much to the steepness of their southern slopes as to their great height. If the ground had sloped more gradually from southern India or beyond to the Tibetan plateau, it seems probable that the height would be a less serious obstacle.

Let us now suppose that the discussion of this first problem has shown that the air, starting from the Southern Ocean as a powerful south-east trade wind and changing to south-west as it crosses the equator, will climb steadily up the surface of the plateau and, crossing the crest, will descend its northern slope. The second problem is: under these conditions, what would be the general weather over the plateau? The air starts at a temperature of about 50°F. and a humidity approaching saturation; if the temperature of the plateau surface is mainly above 50°F. the air will not part with its moisture readily and the cloud amount will be small, but if the temperature of the surface is below 50°F. the sky will be mainly overcast and the rainfall heavy.

Here again much seems to depend on the topography. If the southern margin of the continent was formed by a wide plain at a low level, the air would not at once be forced to rise sufficiently to develop an extensive cloud layer, the low land surface would be very hot, and the air would be warmed up by contact with it to such an extent that it might rise to very high levels before it again became saturated. If, on the other hand, the ground rose fairly steeply from the sea to an elevation of 2,000 feet or so, the formation of a thick cloud layer would begin before the air had time to warm up.

In north-eastern India, where the air crosses the Khasi Hills and enters at least the foothills of the Himalayas, the cloudiness during the south-west monsoon is very great. The mean cloudiness (8 a.m.) at Cherrapunji, Darjiling and Mercara during June, July and August is nine-tenths of the sky, while the relative humidity is 95 per cent. Let us suppose that the southern coast of Gondwana-land being sufficiently steep to raise the incoming trade wind above the saturation level, the mean cloudiness was eight-tenths.

[11] Simpson, G. C., "The South-west Monsoon." *London, Q.J.R. Meteor. Soc.*, **47**, 1921, p. 151.

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The temperature of the air at any point is governed by the quantity of heat which it originally contained, plus the heat which it gains mainly from the surface, minus the heat which it loses, mainly by radiation. L. B. Aldrich has calculated that clouds reflect 78 per cent. of the solar radiation falling on them, so that with a cloudiness of eight-tenths, 62 per cent. of the solar radiation would be reflected back to space by the clouds without benefiting the earth at all. In latitude 0-10° the solar radiation at the limit of the earth's atmosphere is equivalent to 870 gramme-calories per cm^2 per day, and the 38 per cent. available for warming represents 330 calories per cm^2 per day. At present, in latitude 40-50° the mean cloudiness is about six-tenths, and the radiation at the limit of the atmosphere is 650 calories, of which about 305 calories are reflected back to space by the clouds, leaving 345 calories. If we take into account the loss by scattering, especially great during the Permo-Carboniferous because of the great amount of volcanic dust, and the loss by solar radiation absorbed by the air and again radiated to space, both of which would be more or less proportional to the total solar radiation and therefore greater in low than in high latitudes, we see that the amount of solar radiation available for warming the earth's surface was probably less over Gondwanaland than over the ocean to the south of it.

To this it will be objected that the under surface of a cloud layer is also effective in reflecting the terrestrial radiation back to the surface of the earth, and that this would redress the balance. But the reflecting power of clouds for long-wave terrestrial radiation is much less than their reflecting power for short-wave solar radiation. The effect of water droplets on radiation must be similar, qualitatively if not quantitatively, to the effect of volcanic dust, which Humphreys has shown to be thirty times more effective on solar than on terrestrial radiation. It seems therefore that as soon as the air forms a cloud layer, it will not gain any heat from the surface of the plateau. If it continues to rise along a sloping surface, it must continue to form fresh cloud.

Taking the initial temperature of the air as 50°F. and the vertical temperature gradient as 3°F. per 1,000 feet, the snow line will be reached at 6,000 feet. There is no evidence against the supposition that a large part of Gondwanaland was above this height, so that under the conditions postulated, extensive snowfields would develop. The supply of snow would be ample, since precipitation would go on throughout the year, instead of for a few months only as in India, although of course the monthly totals would not equal those experienced at the wettest stations during the height of the monsoon. Hence there would be a plentiful supply of ice to extend below the snow-line on the southern slopes, and to reach the sea along broad fronts.

This brings us to the third problem: once the snow cover had been formed and an inland ice-sheet had begun to develop, would conditions remain favourable, or would the very existence of the ice lead to a change in the meteorological situation which would bring about its disappearance? Ice is very effective in cooling the overlying air, and the existing ice-sheets of Greenland and Antarctica are covered by layers of cold air, causing a local increase of surface pressure often termed a glacial anticyclone. Anticyclones

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are traditionally associated with clear skies, which in the tropics mean hot weather, fatal to the existence of ice. But there is one very important difference between these present-day ice-sheets and that of Gondwanaland; the former are in high latitudes, while the latter straddled the equator. If it were not for the rotation of the earth, the cold air would simply stream off the surface of Greenland or Antarctica, and the glacial anticyclones would not form. On the equator the rotation of the earth does not produce any deflecting force, hence the air cooled by the ice would stream off the surface. On the southern slopes, south of the equator, there would be a tendency for this air-drainage to form a north-west wind, which would come into opposition with the south-east monsoon-trade wind. At the surface both winds would probably prevail in turn—first the relatively mild and moist south-east wind with a light snowfall, then an interval of calm, followed by a blizzard from the north-west, lifting the moist air of the south-east wind bodily and bringing a burst of heavy snow. But these changes would be limited to a shallow surface layer, and over all the south-east wind would blow steadily and the skies would be heavily clouded. The ice-sheet would merely add to the effective height of the land.

The greater part of the Gondwanaland ice-sheet was apparently formed on the southern slopes of the continent, where conditions were most favourable. There can have been very little, if any, snowfall on the northern slope, and for a glacier to reach the Central Sea an exceptional topography would be required. In fact, it happened in only one region—north-west India—and if we may judge from the thinness of the deposits, for a short time only.

What of the glaciation of North America? Fig. 1 shows a long inlet extending from the Arctic Ocean into the heart of the glaciated region, and separated by a narrow land barrier from the Central Sea. These cold and warm surfaces in close proximity would cause exceptional storminess, and probably sufficient snowfall over the high ground for glaciers to reach the sea. Valleys opening southward would be very warm and moist, hence the apparent conflict of evidence. From the glaciation we infer that the Arctic Ocean north of America carried much floating ice, the warm area in northern Russia being due to the local influence of the Volga Sea, just as the warm area south of Spitsbergen at present is due to the influence of the Gulf Stream. The glaciers of Europe, if they existed at all, were probably nothing more than small mountain glaciers such as can develop in any latitude provided the mountains are sufficiently high and the precipitation sufficiently heavy. We know that in late Carboniferous Europe there were both high mountains and heavy precipitation.

There is one peculiarity in the action of volcanic dust which deserves mention. In any latitude its cooling power is about proportional to the solar radiation received at the limit of the atmosphere, while its warming power, though much smaller, is proportional to the radiation from the earth's surface and the lower layers of the atmosphere. The former varies regularly with latitude, while the latter is greatest in the warmest regions. Hence the effect is to increase the abnormalities of temperature brought about by the distribution of land and sea; Gondwanaland was cooled much

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more effectively than the Central Sea, and in Spitsbergen during the polar night the effect was pure gain.

Another point may be mentioned which, though only a speculation, may be of interest. Coal occurs in seams, separated by layers of sand and clay. It is possible that the favourable geographical environment alone was not sufficient for the development of vegetation in sufficient luxuriance to produce coal, the winters being normally too severe, and that a high eccentricity of the earth's orbit was also required, the coal seams representing the periods with winter in perihelion.

Extensive glaciation of the lands now within the tropics has occurred only once in the history of the earth. It presents a very difficult problem, on which I should be glad of the opinions of meteorologists; for myself, I cannot but feel it to be more than a coincidence that this unique occasion was also the only period for which the geographical factors allow the possibility of an inter-tropical glaciation to be argued with any approach to plausibility, and further, that the other climatic peculiarities of the period indicated by the coral reefs, the coal measures and the North American glaciation, occur in just those regions where we should expect them if the continents had their present positions relative to the poles and to the equator.

DISCUSSION.

Dr. HAROLD JEFFREYS said that his feelings with regard to the paper were very much like those of Mr. Bertrand Russell when reviewing a philosophical book a year or two ago; he said that in no respect was it obviously wrong, and in reviewing a work on palæo-climatology as well as one of philosophy that is very high praise. He did not know why Mr. Brooks gave so much prominence to Wegener's theory. What he had really done was to take a reconstruction of Permo-Carboniferous geography that had nothing to do with Wegener, and had shown that its probable consequences would agree reasonably with geological views on the climatology of that period. But Wegener's theory had nothing to do with the paper as far as he could see. Turning to Wegener's theory, we know that the earth's crust is strong enough to hold up Mount Everest and to hold down some of the great deeps of the Pacific, which are as deep as Everest is high. In order to make continents move about, you must apply a force big enough to overcome that tremendous strength, and all Wegener's forces are ridiculously small. In a paper by Mr. Lake read at the Royal Geographical Society a year or two ago, it was shown that the geographical data appealed to by Wegener in support of his theory were very largely incorrect; in particular, with regard to the famous fit of South America into South Africa, you have only got to glance at the map to see that the angles reputed to be equal differ by about 15°, which corresponds to a misfit of some hundreds of miles down at the bottom of the map. On the whole, he thought the case for Wegener's theory was extremely weak, quite independent of what Mr. Brooks had said, while the case against him was extremely strong.

Dr. G. C. SIMPSON said he understood Dr. Jeffreys to say that there was nothing obviously wrong in this paper. He was surprised at that, because he thought that geodesists were now agreed that the crust of the earth underneath the ocean is entirely different in nature from that

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of the continents. If isostasy means anything, it means that the bed of the oceans cannot be raised into continents. The idea of Gondwanaland, therefore, seemed impossible from the point of view of isostasy; but he did not wish to stress that point; he would like to consider Mr. Brooks's suggestions from the meteorological point of view.

Mr. Brooks considered that his continent was high land and that its height accounted for the low temperature, cloud and rain. In considering the climate of such a high continent it is better to proceed in two steps—first, to consider an ordinary low-lying land and determine its climate, and then to consider the effect of raising the surface to the required height. If Gondwanaland were at sea level, it would not be difficult to decide its climate. First, it would be noticed that the greater part of it lies within the tropics and the sun would be vertically over some part of it at all times of the year. There can be little doubt, therefore, that it would be extremely hot. Also, part of it would entirely cover the present Australia, and Australia is a desert with a fringe of land having moderate rainfall. There can be little doubt that this great continent would be a similar desert with a small fringe of vegetation. It would be the hottest continent in the world, much hotter than any existing continent. Now, if mountains were raised on this continent, they would be nearer the equator than the Himalayas and Tibet. Yet there is no permanent snow covering on Tibet in spite of it being over 15,000 feet above sea-level, while all the permanent snow-fields on the Himalayas are above 20,000 feet, and no glacier comes lower than about 10,000 feet. Why, then, should glaciers come down to sea-level on Gondwanaland, much nearer the equator? In his opinion Mr. Brooks's reconstruction of Gondwanaland did not help in any way in explaining the Permo-Carboniferous glaciation.

Dr. Simpson also referred to the evidence of ice in North America, and said he agreed with Wegener that if geologists say that they find on the same horizon and in the same neighbourhood evidence of a hot dry climate and of considerable ice action, then the geologists must re-examine their evidence, for no meteorological theory can account for the two conditions simultaneously.

Dr. L. F. RICHARDSON asked whether Gondwanaland was composed of pale or of dark material, for its tone would affect the fraction of solar radiation absorbed, and hence would affect the temperature. [*Communicated*:—This question would be of importance if the desert alleged by Dr. Simpson existed in patches interspersed between areas of the snow alleged by Mr. Brooks, for the advance or retreat of the edge of the snow would in part depend upon the lightness or darkness of the rest of the surface.]

Mr. L. C. W. BONACINA said that it seemed to him that the possibility of getting a low enough temperature over that big equatorial continent must depend upon an extremely rare combination of favourable circumstances; particularly, it seemed to him, that a very persistent monsoonal current from the cold sea would be necessary because if it were at all intermittent, the temperature would not remain sufficiently low to maintain the snowfield. It was difficult to imagine what the equilibrium temperature would be just where the equatorial glaciers debouched on the sea coast; for, on the one hand, one would suppose they would melt entirely away at low levels, but on the other hand they would, if extensive enough, carry down their own cold. In regard to Dr. Simpson's view, he did not quite agree with him. The deserts at

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the present time are in the trade wind belts in sub-tropical latitudes, and the only desert area on or near the equator at the present time is the coastal strip of Italian Somaliland. The reason of this anomalous equatorial desert was that along the east coast of Africa the atmospheric circulation during the season when the equatorial rain-belt swings northward is dominated by the low pressure centre over the Persian Gulf—in other words, by the Asiatic monsoon system—with the result that the convergence of air currents from the two trades, upon which the equatorial rain-belt depends, is prevented. But if Mr. Brooks's great Permo-Carboniferous equatorial continent were flat, as Dr. Simpson supposes, there would be monsoon currents flowing in from both north and south, giving the normal equatorial rain-belt, even though, owing to the vast extent of land, the rains might not be so heavy as at present.

Mr. C. E. P. Brooks said in reply to Dr. Simpson that he had selected the most recent reconstruction of Upper Carboniferous geography that he could find as the basis for his investigation of the probable climate. He did not think that it would affect the results, however, if America were brought into contact with Europe and Africa. With regard to the climate of the tropical continent of Gondwanaland compared with the present climate of India and Tibet, the essential difference was that whereas in India there is a large area of comparatively low ground south of the Himalayas, Gondwanaland probably consisted of high ground right down to its southern coast, and this would greatly increase the cloudiness. If the sky were very nearly overcast, even a vertical sun could not bring about a high temperature, because of the reflection from the surface of the clouds. The axis of the continent probably lay near its northern coast; the glaciation was almost entirely on the southern or windward slope, the northern slope being glaciated at only one point, India, and even there for a short time only, if we may judge from the relative thinness of the glacial deposits. He thought that at this point the main ridge must have been cut by the head of a valley opening to the northward, so that the glaciers originating from the snow falling on the ridge descended into this valley and flowed northward to the Central Sea or Tethys. Tibet is now on the leeward side of the Himalayas, and the air is naturally very dry, but there are extensive glaciers in the Himalayas themselves, and during the Quaternary glaciation these descended almost to 4,000 feet, which goes quite a long way towards bridging the gap between the 15,000 feet of Tibet and sea-level.

With regard to the North American glaciation, Mr. Brooks said that the evidence was very strong; it had been accepted by an impartial observer and also quite recently by A. P. Coleman, who was the greatest authority on the subject of early glacial deposits. Forests find no difficulty in growing close to glaciers; in Alaska at present they grow even on the terminal moraines above the ice, so that there was no difficulty about the occurrence of glacial deposits and coal-measures in close proximity. He did not think there were any desert deposits in eastern North America during the Upper Carboniferous; the desert deposits quoted by Wegener belonged to the Upper Permian, long after the glaciation, when the climate was quite different.

With regard to Mr. Richardson's question, he did not know what was the colour of the soil; possibly yellow, but the first snowfall would give a white surface.

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THE VARIATIONS OF PRESSURE FROM MONTH TO MONTH IN THE REGION OF THE BRITISH ISLES.

By C. E. P. BROOKS, M.Sc.

[Received January 13—Read April 21, 1926.]

1. The weather of the British Isles is so intimately connected with the sequence of pressure-changes in the region Iceland-Scandinavia-Iberia-Azores that any solution of the problem of long-range weather forecasting for Britain pre-supposes the power of foreseeing the general lines which this pressure sequence will follow, for at least a month in advance. Various lines of research have been devised, one of the most promising of which results from the study of a series of monthly maps of the deviation of pressure from normal over the northern hemisphere or over the world. In this study extensive use has been made of the data collected and charts prepared for the *Réseau Mondial*, which was, in fact, inaugurated chiefly with the object of facilitating long-range forecasting.

The *Réseau Mondial* is a compilation of monthly means of pressure, temperature and rainfall on the basis of two stations for each ten-degree "square" of latitude and longitude. In order to facilitate the study of abnormalities, each monthly mean is given also as the deviation from the "normal" of the corresponding month; by plotting these deviations the permanent or regular seasonal features of the distribution, which would otherwise dominate the charts and largely mask the abnormalities, are eliminated and only the latter remain. In the present notes only the deviations of pressure are dealt with, since it has been found that the deviations of temperature and rainfall in these latitudes at least can be explained almost entirely in terms of pressure.

The first impression obtained from the examination of such a series of charts of pressure deviation is one of hopeless complexity. As an example may be given the charts for March and April, 1912 (Figs. 1 and 2). In March there was a deficit of pressure over Iceland and the British Isles, exceeding 10 mb. over Scotland and Ireland; on the other hand there were areas including the Azores and the Urals, in which pressure was more than 5 mb. above normal. In April the British Isles were covered by an area with pressure above normal, the excess being 10 mb. over Ireland, while the Urals showed a deficit of pressure exceeding 5 mb. From March to April therefore the deviation of pressure from normal over Ireland had changed by more than 20 mb. The question immediately arises as to how this change of distribution came about. Examination of the daily weather charts for March, 1912, shows a large number of depressions. During the greater part of the month they followed slow and tortuous tracks over and about these islands, but towards the end the paths became more regular and the depressions of the 26th to 28th and 28th to 30th passed rapidly eastward just south of Iceland. From April 5th to 10th several more depressions passed eastward between Iceland and Scotland; from the 13th to 16th

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depressions crossed Iceland itself, while later still they moved south-eastward from the Arctic Ocean to northern Russia. During April the centre of no depression actually touched the British Isles; instead an anticyclone moved gradually north-eastward from a position near the Azores during the early days of the month to the neighbourhood of Ireland at its close; this progression is clearly visible on the daily charts although the details of the pressure distribution vary irregularly from day to day. We are evidently dealing with the progressive north-eastward movement of a focus of cyclonic activity and of an anticyclone.

2. In order to study this progressive movement, a series of overlapping thirty-day charts of pressure deviation from normal were constructed. The first chart covered the period March 1 to 30, the second March 2 to 31, the third March 3 to April 1 and so on. These charts showed very clearly the gradual movement in a north-easterly direction of the centres of both excess and deficit. The paths are shown in Fig. 3, the positions at intervals of five days being marked by small circles. It may be remarked

FIG. 1.—Deviation of Pressure from Normal. March, 1912.

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that the numerical values of deviation of pressure from normal in the centres of the areas of both excess and deficit, when plotted gave smooth curves.

Evidently both these centres of maximum pressure deviation moved across the monthly charts in much the same way as ordinary depressions and anticyclones move across the daily charts.

A similar method was adopted by H. Arctowski in dealing with climatic variations from year to year. Most of Arctowski's work was concerned with variations of temperature, but he also discussed variations of pressure.[1] He formed overlapping twelve monthly means for each station (January to December, February to January, March to February, etc.) and found that when the deviations of these overlapping means from the annual normals were plotted, they indicated progressive movements of centres of excess or deficit ("pleions or antipleions"). The character of the movements of these annual centres is however quite different from

[1] Arctowski, H., "La dynamique des anomalies climatiques." *Prat. Mat.-Fiz.*, **21**, 1910, p. 179.

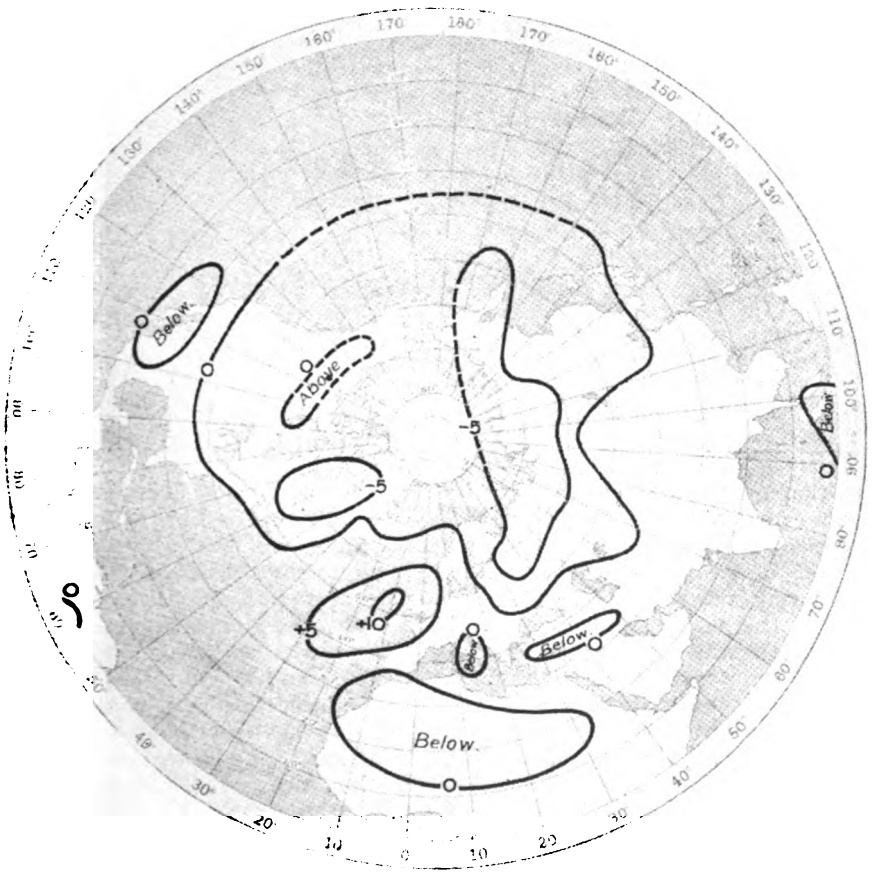

FIG. 2.—Deviation of Pressure from Normal. April, 1912.

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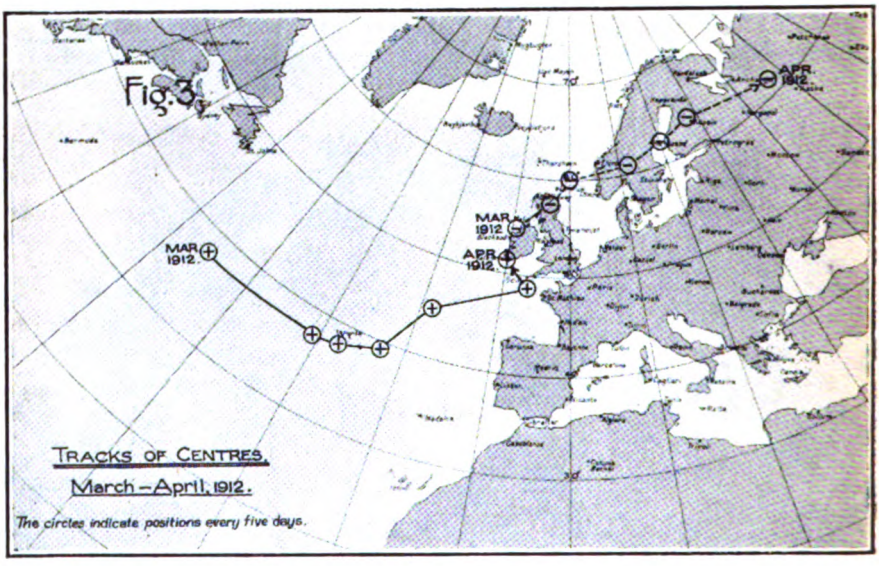
the character of the movements of the monthly centres discussed here. The annual centres usually show irregularly cyclic movement, generally limited to the individual continents, while it will be seen that the monthly centres have usually a progressive movement from west to east.

The direct proof that the progressive movement of monthly centres of excess or deficit is the rule and not the exception would require the construction of a considerable number of overlapping series of 30-day maps. This would be very laborious, and a shorter method was suggested by Dr. G. C. Simpson. If we consider the area between latitudes 30° and 70° N., longitudes 70° W. and 80° E., there are a large number of months in which the chart of monthly mean pressure deviations shows only one centre of excess and only one centre of deficit. For the purposes of this investiga-



tion only those centres were included in which the deviation from normal reached at least ±5 mb. When this occurred in two successive months, a barbed line was drawn connecting the position of the centre during the first month with the position of the centre during the second month. If these centres in successive months were as a rule quite independent of each other, there would be no reason why these arrows should be directed towards one point of the compass rather than another. If, on the other hand, the centres in successive months really indicate two successive positions of the same centre, and if there is a tendency for centres to move in one direction rather than in another, the majority of the arrows should point in this direction. The investigation was carried out on three separate series of charts, which between them cover a period of 41 years:—

(*a*) A series of monthly charts of pressure deviations over the northern hemisphere covering the years 1873 to 1900.

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(*b*) Working charts of deviations of pressure over the globe for the period January, 1910, to April, 1919, prepared in connexion with the *Réseau Mondial*.

(*c*) A series of rough working charts of the deviations of pressure over North America, the North Atlantic, Western and Central Europe, covering the period June, 1922, to October, 1925, prepared in connexion with various investigations into current weather.

The *Réseau Mondial* charts were the first set to be dealt with, and it was quickly evident that the movements of the centres in the southern half of the area were very largely from west to east, while in the northern half there were a considerable number of instances in which the movements were apparently from east to west. The work was accordingly repeated, the pairs of months being separated into two classes, the first class including those in which the position of the centre during the first month was north of 55° N., while the second class included those in which the position of the centre during the first month was south of 55° N. The results of the investigation are shown in Table I.

A word is required as to the relative values of the different charts for the purposes of the investigation. The first group (*a*) includes comparatively few stations, and the probability that a centre of pressure deviation, which only just exceeded ±5 mb., would be missed is therefore greater than in the *Réseau Mondial* charts with their much closer network. This applies especially to Russia, where the standard deviation of pressure is less than in western Europe and where the stations available were less numerous. Consequently it is probable that several instances when in one month a centre lay over western Europe and in the next month a centre lay over Russia or the Urals were missed. If at the same time another centre appeared in the west of the area, the movement would actually appear to have been from east to west. The small number of stations also made it more difficult to localise the positions of centres exactly, and this accounts for the entries under "no change."

Over the land areas and in the neighbourhood of Iceland the *Réseau Mondial* charts were admirably suited for the purpose, but over the North Atlantic Ocean there is a great gap in the network which sometimes made it difficult to specify the position of a centre accurately.

The short series from June, 1922, to October, 1925, contains no observations for Greenland or Russia, but is otherwise sufficiently complete. It was included because for a large part of the period the deviation of pressure from normal had been inserted for a point in the mid-Atlantic, the data being calculated from the International section of the Daily Weather Report.

From Table I. we see that between 70° and 55° N. 60 centres of excess gave an apparent movement to the eastward compared with 35 to the westward, and 60 centres of deficit showed a movement to the eastward compared with 49 to the westward. Between 55° and 30° N. 41 centres of excess showed a movement to the eastward compared with 15 to the westward, and 23 centres of deficit showed a movement to the eastward compared with 16 to

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the westward. In all four groups the easterly movement predominated, although to a much greater extent with centres of excess than with centres of deficit.

TABLE I.—Successive Positions of Centres of Excess or Deficit of Pressure.

Position in second month relative to first month.	Centres of Excess.					Centres of Deficit.				
	NE.	SE.	SW.	NW.	No Change.	NE.	SE.	SW.	NW.	No Change.
I. Centre in first month north of 55° N. :—										
1873-1900 . . .	14	34	13	14	4	7	34	18	17	6
1910-April, 1919 . .	6	6	4	3	0	4	8	4	6	0
June, 1922-Oct., 1925 .	0	0	1	0	2	2	5	1	3	0
Total . . .	20	40	18	17	6	13	47	23	26	6
II. Centre in first month south of 55° N. :—										
1873-1900 . . .	16	3	2	10	0	15	1	3	11	0
1910-April, 1919. .	8	6	1	0	0	4	2	0	2	0
June, 1922-Oct., 1925	6	2	2	0	0	1	0	0	0	0
Total . . .	30	11	5	10	0	20	3	3	13	0
Whole area :—										
Total	50	51	23	27	6	33	50	26	39	5
Per cent. . . .	32	32	15	17	4	22	33	17	25	3

Table II. shows that the predominance of apparent easterly movement holds in all four seasons, though it is greatest in summer. We find that, for each ten centres of pressure deviation giving apparent westward movement in any one season, the number of centres giving an apparent movement to the eastward is: Winter 12, spring 17, summer 21, autumn 16. Taking all these figures into account, we may say that centres of average monthly

TABLE II.—Successive Positions of Centres of Excess or Deficit of Pressure.

Position in second month relative to first month.	Centres of Excess.					Centres of Deficit.				
	NE.	SE.	SW.	NW.	No Change	NE.	SE.	SW.	NW.	No Change
N. of 55° N. :—										
December-February .	5	9	6	4	2	2	12	7	6	1
March-May . . .	6	9	2	5	2	2	12	4	9	0
June-August . . .	2	10	2	2	0	3	8	6	4	2
September-November .	7	12	8	6	2	6	15	6	7	3
S. of 55° N. :—										
December-February .	8	6	3	3	0	4	2	3	4	0
March-May . . .	8	2	1	2	0	8	0	0	5	0
June-August . . .	4	1	0	1	0	5	0	0	1	0
September-November .	10	2	1	4	0	3	1	0	3	0

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pressure deviation actually have a tendency to move across the chart in much the same way as anticyclones or depressions move, and that, like the latter, this movement generally, but not always, takes place in an easterly direction. When the charts are re-examined with this result in mind, it is seen at once that the real predominance of easterly movement is much greater than is shown by the figures in Tables I. and II. Many of the instances of apparent movement to the westward are due to the happening that a centre of deviation which was shown in the chart for one month had by the following month either moved eastward out of the area or had decreased to an intensity of less than 5 mb., while at the same time a new centre of deviation had appeared in the west of the chart. It appears in fact that the month is too big a unit; if the charts had been drawn for each ten or fifteen days the predominance of apparent easterly movement would have been much greater.

The next step was to determine whether these centres followed more or less regular tracks homologous with the "storm tracks" of Van Bebber. For this purpose the *Réseau Mondial* charts for

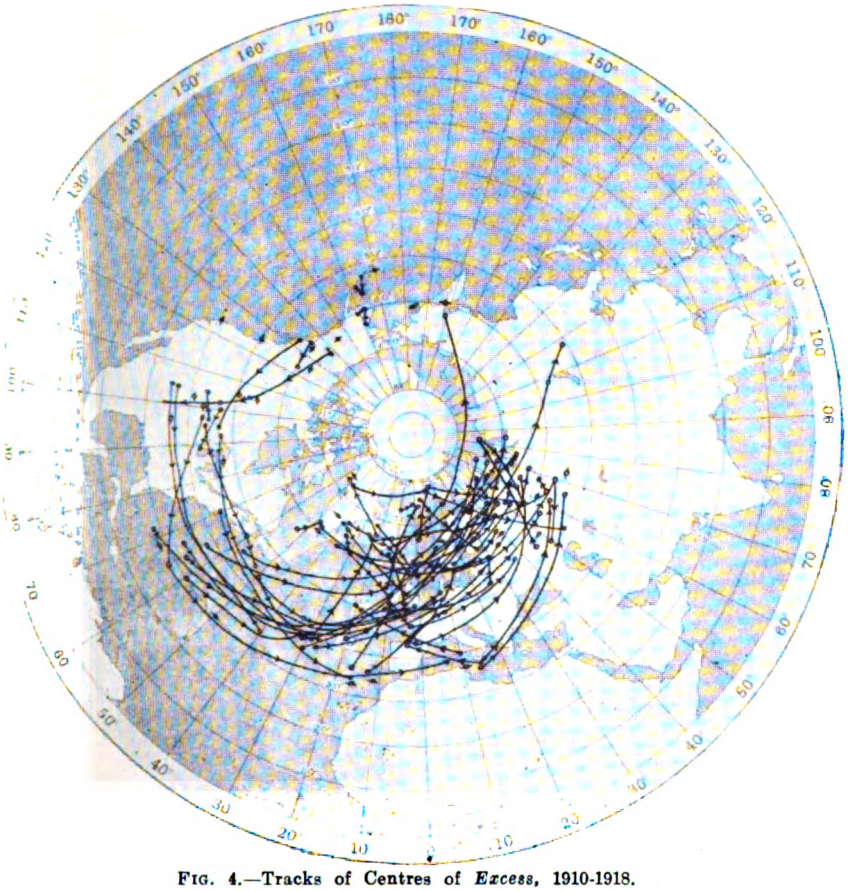

FIG. 4.—Tracks of Centres of *Excess*, 1910-1918.

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the years 1910 to 1918 were examined month by month and the positions of all centres of excess or deficit were plotted on charts of the northern hemisphere, those found in successive months in such positions that they probably represented the migration of a single centre being joined up. The movements of the centres of excess during this period are shown in Fig. 4, and the movements of the centres of deficit in Fig. 5, the small circles representing the positions at intervals of a month. Fig. 4, representing the centres of excess, shows a tendency for a track from Alaska south-eastward to the centre of the United States, thence eastward to a position between Bermuda and Nova Scotia, again eastward to the Azores, then usually north-eastward to the British Isles or across the British Isles to Scandinavia, and finally again eastward into northern Russia or the Kara Sea. The whole journey would take about six months, though actually no single centre was found which persisted long enough to move from Alaska to Russia. The average life of a centre is only about three months, and a certain number appeared suddenly one month and could not be traced in the next. Another track less frequently followed ran from Greenland across Iceland

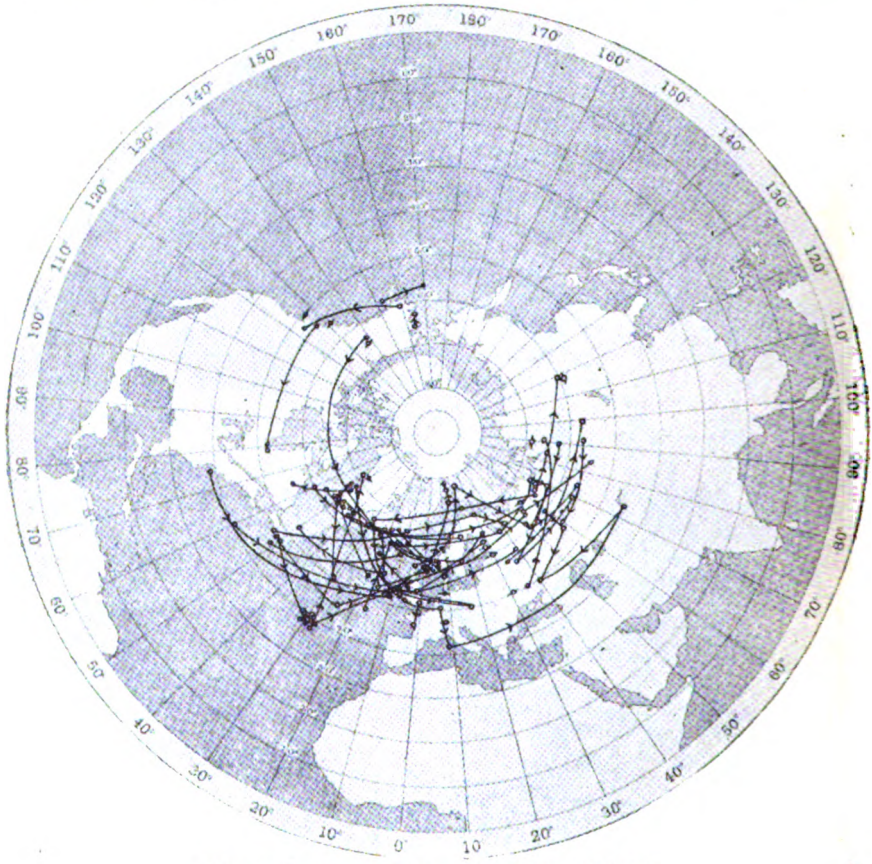

FIG. 5.—Tracks of Centres of *Deficit*, 1910-1918.

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and the Faroes to the British Isles. A third track originated in south-western Europe or between Portugal and the Azores, and passed the whole length of Europe into western Siberia. A schematic representation of these tracks is shown by the continuous arrows in Fig. 6, where they are numbered I. to V. As a rule there is no very definite difference between the conditions in different seasons, but over Europe the northern tracks, II. and III., are mainly followed in summer (April to September), and the southern or continental track, IV., in winter (October to March). In addition to the centres of excess which follow these tracks more or less closely there are a few aberrant centres which follow irregular or abnormal tracks, just as a few depressions on the daily weather maps defy any attempt to reduce them to system.

The paths of the centres of deficit (Fig. 5) are less regular than those of the centres of excess. North America is almost free from centres of deficit; in that continent deficits of pressure occur almost entirely as extensive irregular patches. A number of centres

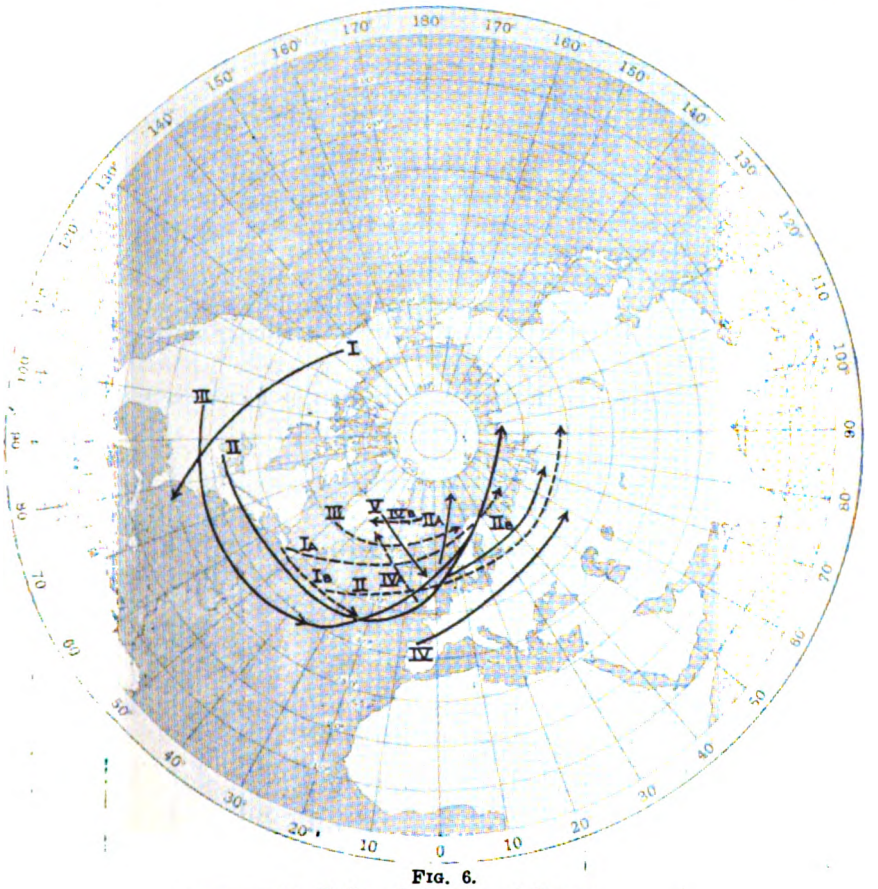

FIG. 6.
Paths of Centres of Excess.
Paths of Centres of Deficit.

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originated in the neighbourhood of Newfoundland and moved in an easterly direction. The path is not so much a regular track as a fan-wise spreading out over the whole area from the Azores to Scandinavia, represented by the area between the broken arrows IA and IB in Fig. 6. The great concentration of centres shown in the neighbourhood of the Azores is due to the limitation of the data to land stations, and it is probable that many of these centres really lay further north over the Atlantic. Most of the Newfoundland centres appear to influence the British Isles in some way during the following month, causing unsettled weather here. Another track (II.) appears to originate in mid-Atlantic and pass directly across the British Isles and along the Baltic to northern Russia, and a third (III.) from south Greenland across Iceland and north of Scandinavia.

The most confusing feature of the chart is the series of tracks between Iceland or Greenland and the British Isles. Centres of deficit most often travel in a north-north-west direction along this track (IV.), but at times follow it in the reverse direction from Iceland towards the British Isles. A very irregular course was followed by a centre which lay over the North Sea in September, 1918, moved north-westward to western Iceland in October, then across to eastern Iceland in November, and had returned to Denmark by December while, in January, 1919, it lay to the south of the British Isles.

3. The study of the tracks of centres of excess and centres of deficit suggests a possible method of forecasting the deviation of pressure from normal for one month from a consideration of the distribution during the preceding month, by methods similar to those employed in daily forecasting. Since the life-history of a monthly "centre" does not occupy anything like so many months as there are days in the life-history of an ordinary anticyclone or

TABLE III.—ORIGIN AND MOVEMENT OF CENTRES OF PRESSURE DEVIATION, 1910—1919.

	Dec. to Feb.		March to May.		June to Aug.		Sept. to Nov.	
	(*a*).	(*b*).	(*a*).	(*b*).	(*a*).	(*b*).	(*a*).	(*b*).
CENTRES OF EXCESS.								
W. Atlantic . . .	2	2	5	2	2	0	1	1
Greenland & Iceland .	3	1	3	2	4	0	4	0
Azores	1	3	3	5	0	1	3	2
Scandinavia . . .	2	0	1	3	1	7	1	5
Europe	2	2	0	11	0	4	0	3
Mediterranean . .	2	1	2	1	0	0	0	0
Russia, 40°-90° E. . .	2	5	2	8	2	7	2	4
CENTRES OF DEFICIT.								
W. Atlantic . . .	3	0	4	0	0	0	1	0
Greenland & Iceland .	6	3	4	3	3	2	3	4
Azores	1	3	1	1	1	3	1	0
Scandinavia . . .	1	3	1	4	0	1	3	5
Europe	3	4	1	4	4	1	2	2
Mediterranean . .	0	0	0	0	0	0	0	0
Russia, 40°-90° E. . .	4	3	3	6	4	2	3	1

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depression, and the monthly tracks, especially of centres of deficit, are even less regular than the day to day tracks of depressions, the process evidently requires a great deal of care.

In order to estimate the chances of success in a forecast based only on the movements of centres of excess or deficit, Table III. has been prepared, showing for each season for a number of areas, the numbers of centres which (*a*) originated suddenly in the area, or (*b*) moved into the area from some other region.

A centre which moves into any region from outside, so long as it follows the normal track, would give a generally successful forecast; a centre which appears in that region with no previous sign of its existence would give a failure. Hence as a preliminary test of the possibilities of forecasts deduced from the tracks, unaided by any other consideration, we may take (*b*) as successes and (*a*) as failures. This gives us the following frequency of successes and failures in Europe (Table IV.):—

TABLE IV.—PROBABLE RESULT OF MONTHLY FORECASTS FOR EUROPE.

	Successes.	Failures.
December to February . .	6	5
March to May	15	1
June to August . . .	5	4
September to November . .	5	2

From this table we should expect a reasonable amount of success in spring but doubtful results during other seasons. Evidently some improvement in the methods is required before long-range forecasting from the movements of centres of pressure deviation can promise success. Forecasts based on the movements of centres of excess in general offer greater chances of success than those based on the movements of centres of deficit.

4. Here again we may take a lead from daily synoptic forecasting. The daily forecaster does not trust only to the normal tracks of depressions; he obtains information as to the direction in which a depression or anticyclone is actually moving at the time of observation by means of the "barometric tendency," or rate of change of pressure at a number of places. That is, he has not only the actual pressure but the differential coefficient dp/dt. In the same way, by examining the daily charts for the last few days of the month, we can prepare a rough chart of the deviation of pressure from normal during that period. The difference between this chart and that for the whole month gives us a monthly "barometric tendency" which will at times usefully supplement the chart for the whole month.

5. So far we have been proceeding on purely empirical lines and have not even discussed the causes which result in these more or less systematic movements of centres of excess or deficit.

The important point is the cause of the prevailing easterly movement of centres of pressure deviation. If this were limited to the oceans, it would present no difficulty, since we could postulate the effects of abnormally warm surface water on the eastern side of

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a negative centre and cold surface water on the eastern side of a positive centre. Since the movements apparently take place equally readily over the land, this facile explanation is not tenable, and it has to be admitted that the cause of the movement is at present unknown.

The movements of individual depressions are much more rapid than the movements of the monthly centres of deficit of pressure, and the latter can only be defined as "foci of cyclonic activity during the month." Many anticyclones are intimately connected with depressions, and move with them as part of the same system. On the other hand, some of the larger anticyclones, such as that referred to in the last part of paragraph 1, appear to have an existence independent of the passage of depressions, and these anticyclones move very slowly. A chart of the movements of barometric maxima between 1883 and 1887 given by van Bebber and Köppen[2] shows a series of tracks from western Canada across the United States and the Atlantic mainly between latitudes 25° and 40° N. From the neighbourhood of the Azores the tracks run generally north-eastward across western Europe into Russia. The whole system of tracks presents an extremely close resemblance to that shown in Fig. 4, and it seems probable that in many instances the tracks of the centres of excess actually represent essentially the tracks of the large slow-moving anticyclones, on which more rapidly moving phenomena may or may not be superposed. The tracks of the centres of deficit are much less regular, but Fig. 5 seems to show two fairly systematic features, a group of tracks spreading out from the east coast of North America, especially near Newfoundland, in directions between ENE and ESE, and a track from the ocean south-west of the British Isles north-eastward across Scandinavia. The former is very reminiscent of the spreading out of the waters of the Gulf Stream, and may represent a tendency of foci of cyclonic activity to follow the path of masses of abnormally warm water across the Atlantic. The north-eastward movement of centres of deficit across the British Isles and Scandinavia appears to be closely related to the very definite track of the centres of excess from the Azores to the British Isles. Examples similar to that illustrated in Fig. 3, in which a centre of deficit moved from Britain to northern Europe while a centre of excess was moving from the Azores to Britain, occurred nine times during the period 1910-1918 covered by the *Réseau Mondial* charts (February-March, 1910, March-April, 1912, June-July, 1913, December, 1913-January, 1914, March-April, 1914, February-March, 1915, April-May, 1915, August-September, 1917, and November-December, 1917). It is noticeable that of these nine examples five occurred in spring. These instances suggest that there is some dynamic connexion which causes the tracks of depressions to come to a focus of activity at a point some distance to the north or north-east of the slow-moving anticyclone, and it is possible that there are similar connexions in other parts of the region.

6. Before these results can be employed as the basis of regular

[2] van Bebber, W. J. and W. Köppen, "Die Isobarentypen des Nordatlantischen Ozeans und Westeuropas." *Hamburg, Aus. d Arch. Seewarte*, **18**, 1925, H.4, Tafel 2.

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long-range weather forecasts with as much confidence as daily charts are employed for daily forecasts, it will be necessary to have some means of foreseeing the sudden appearance or disappearance of centres of pressure deviation, and also the aberrant tracks which these centres sometimes follow. There are still several difficulties in the way of obtaining this information, and all that can be done here is to indicate the working hypothesis which has been taken as a basis for further research. It is known from the investigations of Sir Gilbert Walker and others that the seasonal means of pressure in any region show relationships with the preceding or subsequent conditions in other regions, sometimes far distant. Among the factors which influence the subsequent pressure distribution in the North Atlantic and western Europe the strength and temperature of the Gulf Stream and the variations in the amount of Arctic ice are known to be included, but there are undoubtedly others, and the most important effects are probably dynamical rather than thermal in origin. The working hypothesis supposes that it is these major variations in the pressure distribution which govern the origin, movement and disappearance of the monthly pressure anomalies. To take an example, suppose that a pressure anomaly of + 5 mb. is centred over the Azores. Following the normal track, this centre should move slowly north-eastward, but if the preceding world conditions favour low pressure over the British Isles, we suppose that the centre over the Azores will either die out or follow an aberrant track. Some data have already been obtained which support this hypothesis, but before it can be completely tested a large number of possible factors have to be analysed, each of which requires a separate, often laborious, investigation.

DISCUSSION.

The PRESIDENT (Sir Gilbert Walker) referred to the eastward motion of the areas of greatest positive and negative departures from normal of the monthly mean pressures; he said that this was clearly dependent in part on the varying eastward motion of the actual cyclones and anticyclones, and suggested that the working out of the relation might be of interest.

Mr. L. C. W. BONACINA said that he would like to draw attention to the statement in Mr. Brooks's paper in which he says: "Among the factors which influence the subsequent pressure distribution in the North Atlantic and western Europe, the strength and temperature of the Gulf Stream and the variations in the amount of Arctic ice are known to be included, but there are undoubtedly others, and the most important effects are probably dynamical rather than thermal in origin." That seemed to be proved by the fact that where as in England, where the pressure variability is great the temperature variability is much smaller than in a continental region like Russia where the pressure variability (as Mr. Brooks had observed) is smaller.

Mr. C. E. P. BROOKS, in reply to Sir Gilbert Walker's remarks, writes: "A clear case of the varying eastward motion of depressions occurred in 1924. In May there was a centre of pressure deficit over Ireland, and out of five primary depressions which crossed the British Isles, three filled up in the North Sea without reaching the continent

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of Europe. There were also several secondary depressions which reached the British Isles and then filled up. In June, on the other hand, the centre of deficit lay over Scandinavia and all the depressions crossing the British Isles passed on to the continent of Europe. Generally speaking, at the centre of pressure deficit the depressions slow up and follow irregular and tortuous paths."

Revolving Pilot Balloons.

We have received the following letter which raises a point of some interest, and to which Mr. L. H. G. Dines attaches a few comments:

"We are all familiar with the fact that clouds at different altitudes frequently travel in different directions. Also that pilot balloons change their directions during their ascents.

"It would be expected that a pilot balloon would also revolve during its ascent. Do pilot balloons change their revolutions with their change of direction? Have there been observations on the revolutions of pilot balloons?

"The answer to these two questions might interest other people besides myself."

F. J. GURNEY.

East Colne, Essex.
April 16, 1926.

In regard to Mr. Gurney's two questions, I do not know of any data on the revolution of pilot balloons in flight.

I think that sometimes they do revolve, but that for several reasons very little of interest could come out of investigations into the question.

An inflated balloon is never perfectly symmetrical in shape and any little irregularity will, in a steady stream of air such as is provided by its rising velocity, tend to produce a slight unbalanced force. Such a force stands a very large chance of having an acting moment about the vertical axis of the balloon, in which case as the latter rises it will rotate in a definite direction. As the balloon expands further, its unsymmetricality may change and the rotation may cease or even reverse its direction.

When a balloon rises through air whose velocity is uniform, the only relative air velocity which it will experience is that due to its own vertical motion, but if the atmosphere be turbulent, it is conceivable that the balloon may experience some slight rotational force at times in either direction. Since, however, the eddies encountered will be very large compared with the dimensions of the balloon, the angular velocity which they might be capable of imparting to it will be very small and is likely to be entirely masked by the steady rotational effect which an unsymmetrical shape can produce. The latter is of no particular interest to the student of atmospheric motions, but it is the only rotational effect which could readily be observed with any accuracy.

L. H. G. DINES.

June 8, 1926.

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REPORT ON THE PHENOLOGICAL OBSERVATIONS IN THE BRITISH ISLES FROM DECEMBER, 1924, TO NOVEMBER, 1925.

No. 35, NEW SERIES.

By J. EDMUND CLARK, B.A., B.Sc., IVAN D. MARGARY, M.A., AND RICHARD MARSHALL, F.R.A.S.

Our heading shows that we have now completed 35 years, a period often found important in meteorology. Fresh averages have therefore been worked out and used for comparison. The changes from the 30 years, as shown, for instance, in Tables IV. and VIA., are comparatively slight for districts where the returns are fairly complete. Scotland N falls sadly below this standard, and there are serious lacunæ in Scotland W and the western half of Ireland, although the total of our stations, 362, practically equals the high-water mark of 1924.

Entering with 1926 into the second quarter of this century, it is gratifying to report the very encouraging response to our appeal, noted last year, for closer international co-ordination. In a third communication to *Nature*, on March 20 last, we were able to put ourselves into touch with nine other European Associations working on similar lines. There were thus ten lists available for comparison, and your Committee has based on them a schedule of 32 plant observations, with the addition of those on birds and insects in our Table VI. Our indebtedness to a large number of our splendid corps of observers, who are undertaking, in part or whole, the additional records in the international schedule, will be further increased.[1]

We also referred, last year, to the accidental rediscovery, after an interval of over a hundred years, of the phenological records kept by the Marsham family at Stratton Strawless, Norfolk, from 1736, and which are still being maintained. These formed the subject of an important contribution, presented at our last December Meeting by Mr. I. D. Margary. In Table IX., and notes, some of the more salient results are included.

The dates in the tables and text give the days which have elapsed from New Year midnight. Hence December 1 is −31; February 1 is 32; March 1 is 60, and so on. Limits of space entail the omission from Table III. of all records under 7, except in sparse districts; in VI. of less than three birds and three insects; in VII. of less than 9 of the 28 migrants. But all records appear in the original tabulation and are used in working out the mean value of each event. Further, these records are stored for possible reference, together with all the original schedules, from which also

[1] Reprints of the above letter are available upon application. Since this was written we hear from Her Asche Moe that the Norse University of Agriculture is organising phenological observations, through the Schools of Agriculture. Response has come also from the fine Swedish organisation.

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is abstracted a digest of the notes, arranged under ten or more different subjects.

WEATHER SUMMARY: "A normal year; a wet May; a sunny and abnormally dry June; wintry conditions November and December."[2]

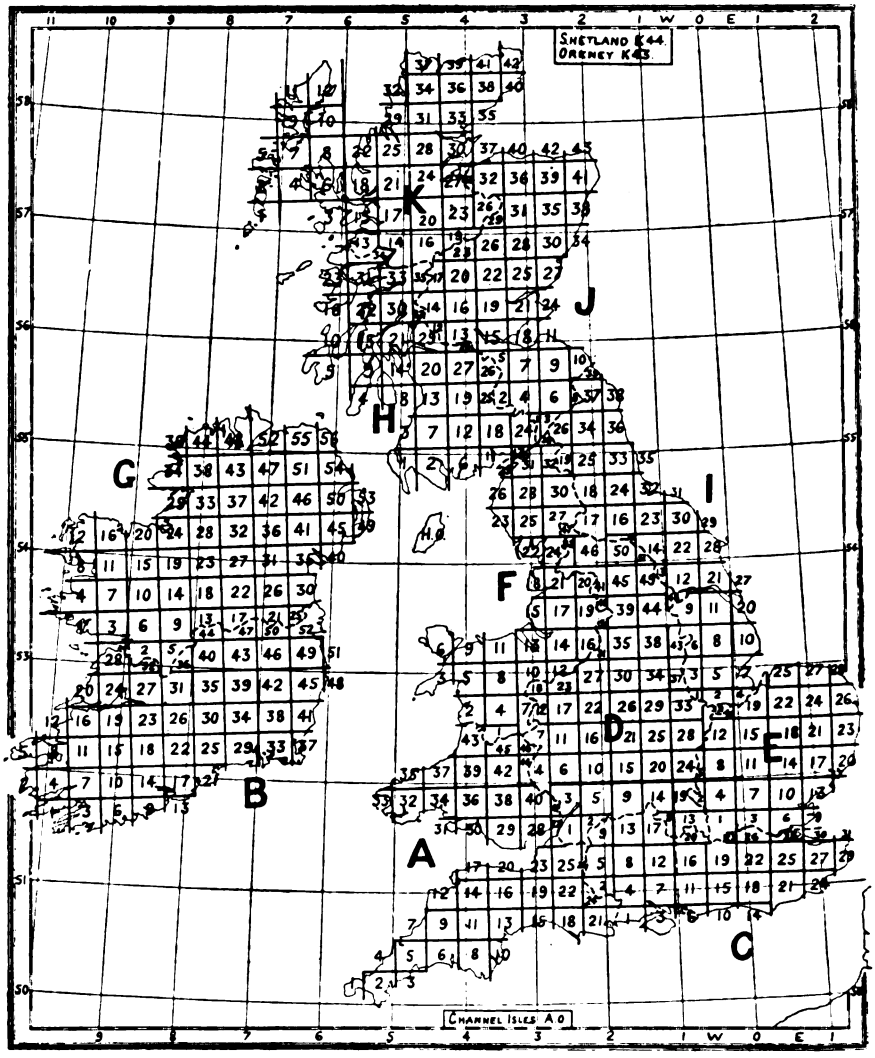

FIG. 1.—Phenological Districts and Areas.
The station numbers are derived from the numbers shown here.

For the wintry December of 1925, our period, December 1924 to November 1925, substitutes its precise antithesis, officially summarized as "warm, generally wet and stormy." Warmth was

[2] Meteorological Office Monthly Weather Report. Summary for 1925.

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most outstanding, and was unequalled, for instance, in Southport's 54 years of observations, except in 1898. At the naturally mild Torquay, not a single ground frost occurred. The most northerly parts were relatively warmest, with temperatures more than 5° above the average. It was the mildest Scotch December for at least 60 years. The mean temperature at Lerwick, Shetlands, 45°.7, was hardly exceeded at St. Heliers, Jersey, 46°.0, the Channel Isles being relatively the coolest district. Their latitudes are, respectively, 60° 9′ and 49° 11′ N.

The other winter months were also warm and wet. March dryness, fortunately, relieved serious seeding anxiety, though colder weather up to early May checked growth and wheat suffered on heavy soils. Warmer rains later on saved grain crops during the prolonged June drought and heat, which was broken by a cold closing week. The drought in some parts lasted well into July, turnips especially suffering. Dryness, indeed, marked all three summer months in Scotland and Ireland, with absence of sunshine after June, save for brief intervals.

September was wet and cool; October the reverse, enabling fair recovery of belated harvests. The second week of the next month ushered in the severest spell of November winter since 1919. This lasted on and off until Christmas. Such contrary conditions resulted in our phenological year diverging from normal by only +0°.6 F., an inch extra rainfall and very slight excess of sunshine. The actual Calendar Year, 1925, hardly diverged at all.

Tables I. and Ia. present regional details. Ia. is particularly informative as to the dependence on warmth of growing conditions. Winter, spring and summer each gave an excess of accumulated temperature above 42° over the average for the British Isles. The only district exceptions were for the Channel Islands, England SW, Ireland S and N, and Scotland E during spring.

Warmth excess was greatest in December and January, rainfall in February and May, and sunshine in June and November. The reverse held respectively in September and November, March and June, May and September.

Isotherms and Isohels (Fig. 2, December 1924—July 1925). Compared with 1924 the former are generally 1° F. further N in Ireland and England SW to 2° in England E and Scotland E and N. The up-rush of warmth from the Bristol Channel to the S. Yorkshire coast is strongly developed. Over England an unusual gap lay between 49° and 48°. Isohels range from 5 hours some 30 miles inland from the S. coast to under 3 hours in the Orkneys, though the Shetlands had half an hour more. Over 1924 the increase is roughly half an hour, rising to an hour along the Irish Sea. Hull, S.W. Lancs. and Glasgow are again centres of gloom. As usual, coastal regions are most favoured.

Floral Isophenes (Fig. 3; based on the 12 plants, hazel to bindweed). The features of our 1925 map are much simpler than those of 1924. England SW was later than 1924, isophene 117 being replaced on the coasts by 124. S.E. Ireland also was rather late. Elsewhere, 1925 was decidedly earlier. The chief isophenes, 124 and 131, crossed the Midlands on the lines Chester-Gloucester-Yarmouth and Manchester-Sheffield-Hull-Norwich, or nearly the routes of 131 and 138 in 1924. Isophene 124 clearly defines the

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Severn up-rush, extending to the Cheshire coast and also over the South Midlands. This feature was almost eliminated in 1924. The same earliness appears in the later areas in the Pennines and Scotland. Even the latest (152) are less extensive than were those of 159 the year before. Eastern Ireland appears somewhat later. Here improved distribution of stations make the isophenes more reliable; their N and S trend is unusual.

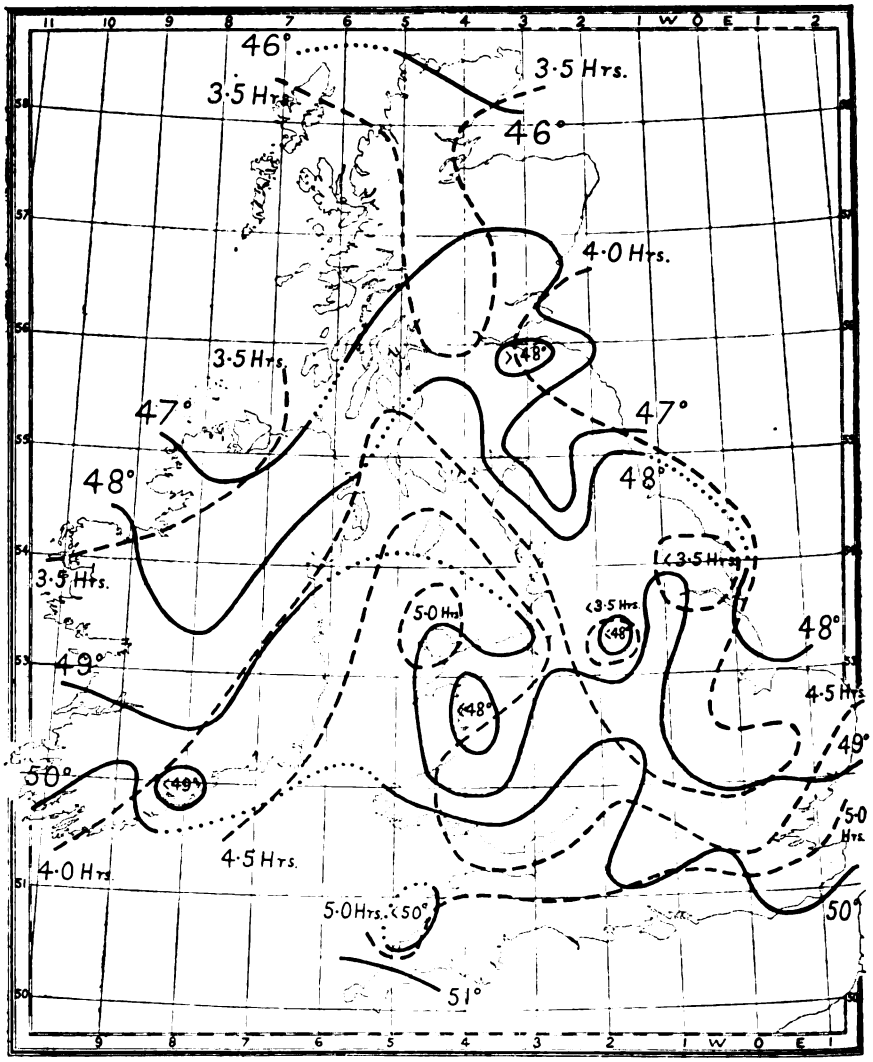

FIG. 2.—Isotherms (reduced to sea-level), or lines of equal temperature, and Isohels, or lines of equal sunshine, during the eight months December 1924 to July 1925.

Isotherms ——— Isohels — — — —

ISAKAIRS. Comparison with the 30-year average isophenes is this year facilitated by Fig. 4, which shows the lines of equal

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divergence from the average date. For these we propose the term *isakairs* (lines of equal unseasonableness). In addition to the map for 1925, those of the latest year (1891) and earliest year (1893) are included for comparison, based on unpublished isophene maps of the usual type, recently constructed for these years. The isakairs show the distribution of differences of 5, 10, 15 and 20 days from the average isophene dates of the locality. The year 1891 shows universal lateness, *increasing* from W to E, the isakair + 10 days embracing nearly all England except the Devon-

FIG. 3.—Weekly Floral Isophenes, or lines of equal flowering dates, from 117 to 152.
117=April 27. 131=May 11. 145=May 25.
124=May 4. 138=May 18. 152=June 1.
1925 ———— Average (30 years 1891—1920) — — — —
(The effect of high ground is clearly evidenced, especially in the North.)

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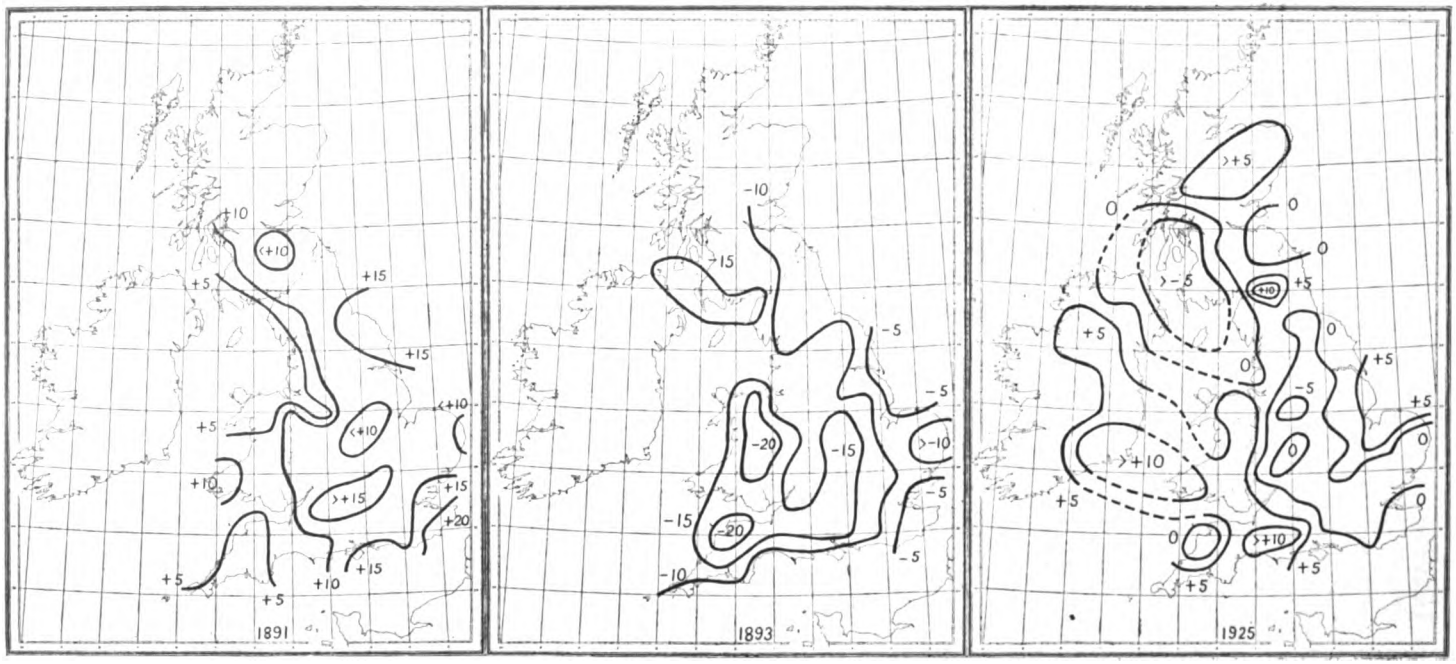

FIG. 4.—Floral Isakairs, or lines of equal divergence (*Gr. isē akairia* equal unseasonableness) from the average flowering date, for the years 1891, 1893 and 1925.

The lines indicate the distribution of differences of 5, 10, 15, and 20 days before (−) or after (+) the average date of the region.

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Cornwall peninsula, while the isakair + 20 days appears over Kent. In 1893, earliness was everywhere, but *decreased* from W to E, giving Central Wales and N. Devon −20 days, while isakair −10 days included all the W. Lowlands and all England south of the Tees and west of the line York-Brighton. These two maps appear to indicate the dominating continental influence in extreme years, increasing the lateness in the east in 1891 and neutralising the excess of sea-borne warmth in 1893. Lack of data prevents the extension of the maps to the Highlands and Ireland.

In comparison, the map for 1925 is more complex, due perhaps to the absence of such phenomenal weather conditions as occurred in 1891 and 1893. The main features are a large, late area covering S.E. Ireland, S. Wales, with an extension over Somerset and Dorset, in all of which isakair + 10 days occurs; an early region covering N.E. Ireland and S.W. Scotland; a late area over the Highlands; and another small, late area on the high ground near Carlisle, which also shows isakair + 10. The Midlands, England E and SE showed little departure from normal.

A comparison with the isotherm distribution, Fig. 2, shows natural correspondences. Earliness and warmth stretch from the Cotswolds to S.E. Yorks, and recur near the Firth of Forth and over the S.W. Highlands. Lateness and coolness occur over S. Wilts and E. Dorset, Central Wales, round the Wash, near the Scotch borders, SE from Cork, and over north-central Ireland. But there are one or two slight discrepancies; the north Welsh coast and Aberdeenshire are late and warm.

Fig. 5 brings out in a practical way the unusually small variation from district to district. As a rule it can hardly be compressed into 63 lines. For 1925, 48 lines were ample. Six of the 13 occupy only three lines each: in 1924 the dog rose alone. Among other problems suggested are the contrasts between hazel and coltsfoot, and of black knapweed with greater bindweed and harebell, the periods overlapping in each case.

This figure, with Tables IIIA. and IV., indicates seasonal changes. Over England and Wales, earliness prevailed up to the flowering of the blackthorn in the last week of April, the coltsfoot by as much as 10 days. Lateness ensued, lasting into July, except in England SE, when a return to normal is shown by the dog rose. The final averaging gives a "normal" year. For the whole British Isles the blackthorn itself was normal, and after that date divergence was very small. District lateness reached 7 days in Ireland S, in contrast with the 6 days early of Scotland W.

MR. LOWE'S RECORDS. At the end of Table VIII. we add the difference from the 10 years' average, which he gave us last year for 7 trees. The hazel alone was early in flower, the mean lateness being 5 days. Fruit ripening was 4 days late and autumn colouring early, full tint and bare boughs by nearly a week.

INSECTS OF TABLE VI.—All five, except the last, are later than the 35-year average, most notably the honey bee, nearly a fortnight late in England and Wales, the wasp and orange tip being some weeks later. Turning to districts, we find the bee up to date, February 27, only in England SW, lateness increasing to three weeks in the Midlands, Ireland N, England NE, and to four weeks

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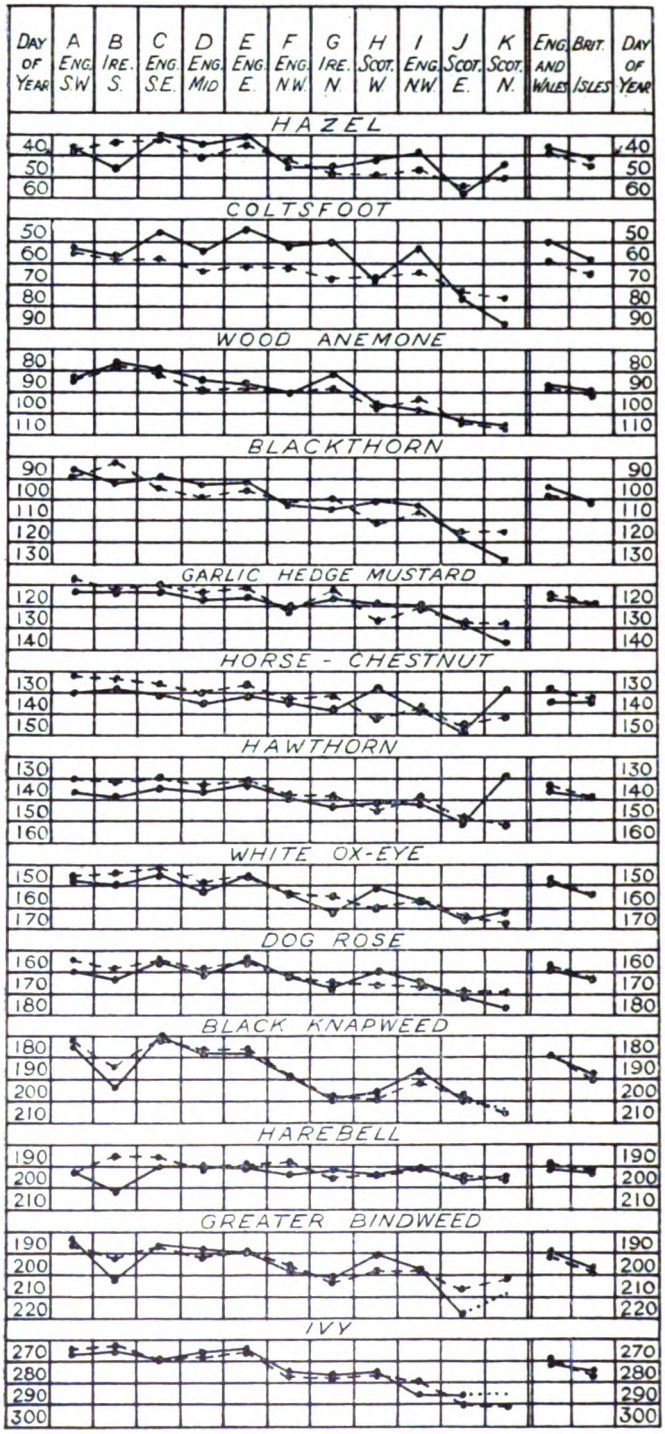

FIG. 5.—Dates of Flowering of Plants by Districts.

1925———— 30 years' average --- - --- - Conjectural . . . . .

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(April 2) in England NW. The wasp ranges from 17 days early in Scotland W, to 14 late in England SW. The very abnormal date, seven weeks early in Ireland S, is very doubtful on account of scarcity of observations; another was too precocious, and three far too late. As this leaves three records only, it is none too reliable. Yet it represents the abnormal early winter warmth; *cf.* Table I. In Scotland N the comparative earliness of orange tip and meadow brown may possibly be due to the excess of midsummer daylight. But more stations are necessary in K. to verify such a point.

MIGRANTS (Tables VI., VIA., VII., VIIA., and Fig. 6). Arrival dates in 1925 have been more regular. Only three, and these rarer birds, average over four days late; three only were a little early. Three extra columns in Table VII. show mean arrival dates of the earliest six, the middle 11 and latest 11. The first were most

FIG. 6.—Migrant Isophenes (lines of equal arrival dates) 1925. Based on the 28 birds and 131 stations of the Migrant Table. See Table VII.
Also Isophene Stations 1925: Floral •, Migrant ×, Floral and Migrant ⊠

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retarded. We also show their mean values for the districts. Comparison should be made with the migrant isophenes; the whole 28 are a day and a half behind the 10 years' average.

ADDITIONAL SPRING MIGRANTS. Ring ouzel (16 records), 103 or April 13; pied flycatcher (6), 121 or May 1. The records in 1924 were 22 and 21 respectively.

OTHER MIGRANT MOVEMENTS (VIIa.). Nos. 1 to 3 and 5 to 9 average in each case three days early, say, January 31 and September 27. Thus these extensions, giving bird records earlier and later than those shown by the migrant tables, indicate respectively the effect of the winter mildness and the early autumn coolness. Both are confirmed by Table VI. The thrush is eight days early; the departing swallow seven days.

MIGRANT ISOPHENES. These are based on over 3,000 records from 131 stations, practically the same number as last year. The general trend of the isophenes differs little from 1924, but the late areas are more extensive, except at our S and SE coasts. Here isophene 115 extended further inland, while 112 (absent in 1924) appears on a narrow coastal strip—clear indications of earlier arrival subsequently retarded. Elsewhere, lateness is shown by the more southward extension of isophenes 117 and 121 in 1925. In Scotland the isophenes for 1924 and 1925 are almost identical. Lack of data renders Ireland uncertain, but the exceptional earliness indicated south from Belfast over Co. Down can hardly be ignored, for the same characteristic is shown on the maps for both 1923 and 1924. In 1923 isophene 115 occupied almost the same position as is shown now, and in 1924 isophene 118 makes a similar northward loop.

THE SIX BIRDS OF TABLE VI. The mean of the three migrants, recorded in all districts, agrees with the 35-year average. The Table VII. average is for ten years only. This may be comparatively late, perhaps by a day. Hence the difference of one and a half days may, when it can be tested, prove to represent no actual divergence. Graphs worked out by Mr. Marshall of the six birds from district to district, corresponding to Fig. 5 for plants, bring out an interesting relation for the 35 years of the arrival date of the cuckoo compared to the swallow, the two birds for which our returns are most complete and therefore reliable. It is shown yet better by plotting the differences on a map of the districts. The cuckoo comes later as follows:—C and E, 2 days; D, 3; I and J, 5; A, 6; F and H, 7; B and G, 10; but K, −1. In other words, passing westward from the SE, relative lateness grows by 8 days on reaching Ireland; up the N.W. coast, 5 days to the Solway and Scot. W; up the N.E. coast, 3 days to Berwick and Scot. E. In Scot. N the cuckoo actually outflies the swallow and arrives first. Is this, too, associated with the long daylight hours? This was so unexpected that all the 35 years' records have been re-examined and those only selected where both were observed, 65 cases in all. The result is still the same. It is spread over 32 of the 35 years, in 16 of which the cuckoo came first; in 16 the swallow. A comparison with Table V. shows no close association with the flowering, early or late; but that table includes only England and Wales.

(*Continued on page* 297.)

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TABLE I.—Variations from the Average in Temperature, Rainfall, and Sunshine, 1924-25.

Daily Mean Temperature.

Months.	Mean Dis. A—J.	Chan. Islands	A. Eng. S.W.	B. Ire. S.	C. Eng. S.E.	D. Eng. Mid.	E. Eng. E.	F. Eng. N.W.	G. Ire. N.	H. Scot. W.	I. Eng. N.E.	J. Scot. E.	K. Scot. N.
		11.	8.	10.	5.	4.	3.	7.	9.	6.	2.	1.	0.
1924.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
December .	+4.3	+1.3	+3.6	+3.6	+3.2	+4.6	+3.8	+5.2	+4.2	+4.7	+4.4	+5.2	+5.2
1925.													
January .	+3.1	+2.5	+3.3	+2.8	+3.5	+3.2	+3.7	+3.0	+3.1	+2.9	+2.5	+2.5	+3.5
February .	+1.3	+1.6	+1.8	0.0	+2.4	+2.1	+2.7	+2.3	−0.1	+0.5	+1.5	+0.3	+0.4
Winter .	+2.9	+1.8	+2.9	+2.1	+3.0	+3.3	+3.4	+3.2	+2.4	+2.7	+2.8	+2.7	+3.0
March .	−0.1	−1.1	−0.9	−0.1	−0.9	−0.4	−0.4	−0.1	+0.7	+0.6	0.0	−0.1	+0.6
April .	−0.8	−0.7	−0.5	−1.2	−1.1	−0.6	−0.1	−0.6	−1.3	−1.1	−0.3	−1.5	0.0
May .	+0.6	−0.7	−0.2	−1.3	+0.9	+1.5	+2.7	+0.8	−1.0	+0.2	+2.2	+0.5	+1.2
Spring .	−0.1	−0.8	−0.5	−0.9	−0.4	+0.2	+0.8	0.0	−0.5	−0.1	+0.6	−0.4	+0.6
June .	+1.2	+2.1	+2.4	+1.8	+1.4	+1.5	+0.6	+1.2	+0.5	+1.4	+0.3	+1.1	+1.3
July .	+1.6	+0.3	+1.2	+0.4	+1.3	+2.3	+2.1	+2.0	+0.3	+2.3	+2.4	+1.8	+3.0
August .	−0.7	−0.4	+0.7	+0.5	−0.2	+0.9	+0.8	+1.0	+0.5	+0.9	+1.0	+0.4	+0.9
Summer .	+1.2	+0.7	+1.4	+0.9	+0.8	+1.6	+1.2	+1.4	+0.4	+1.5	+1.2	+1.1	+1.7
September .	−2.6	−2.7	−2.4	−1.8	−3.5	−2.7	−2.8	−2.5	−2.0	−2.3	−2.6	−3.0	−2.1
October .	+1.9	+1.7	+2.2	+2.6	+1.9	+2.2	+2.2	+1.6	+2.5	+1.6	+1.4	+1.3	+1.2
November .	−3.8	−3.1	−4.5	−3.7	−3.9	−4.2	−2.3	−5.3	−2.1	−3.9	−4.4	−3.5	−1.7
Autumn .	−1.5	−1.4	−1.6	−1.0	−1.8	−1.6	−1.0	−2.1	−0.5	−1.5	−1.9	−1.7	−0.9
Year. Dec.—Nov.	+0.6	+0.1	+0.6	+0.3	+0.4	+0.9	+1.1	+0.6	+0.7	+0.7	+0.7	+0.4	+1.1

+ indicates above the average, − below it.

Total Rainfall.

[25 millimetres practically equal 1 inch; hence 0.04 inch equals 1 mm.]

	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1924. December .	+21	− 3	+22	+ 59	+25	+17	+ 7	+24	+24	+27	− 4	+14	+58
1925. January .	+ 2	+43	+13	+ 40	+24	− 1	−14	−12	− 3	− 8	−11	− 4	− 4
February .	+41	+35	+62	+ 49	+50	+33	+18	+62	+40	+14	+23	+49	+24
Winter .	−64	+75	+97	+148	+99	+54	+11	+74	+61	+33	+ 8	+59	+78
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
March .	−32	−42	−54	−65	−35	−29	−11	−36	−36	−36	−12	− 4	−11
April .	+22	+37	+15	+34	+17	+ 7	+10	+11	+30	+49	+21	+28	+22
May .	+41	+53	+57	+57	+30	+40	+ 5	+43	+45	+80	+18	+36	+41
Spring .	+31	+48	+18	+26	+12	+18	+ 4	+18	+39	+93	+27	+60	+52

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TABLE I.—VARIATIONS FROM THE AVERAGE—*continued.*

Total Rainfall—continued.

MONTHS.	Mean Dis. A—J.	Chan. Islands. 11.	A. Eng. S.W 8.	B. Ire. S. 10.	C. Eng. S.E. 5.	D. Eng. Mid. 4.	E. Eng. E. 3.	F. Eng. N.W. 7.	G. Ire. N. 9.	H. Scot. W. 6.	I. Eng. N.E. 2.	J. Scot. E. 1.	K Sco N. 0.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm
June . .	−50	−45	−57	−56	− 45	−54	−39	−58	−50	−51	−48	−30	− 2
July . .	− 1	+ 5	+10	+ 6	+ 30	0	− 5	−22	+22	−22	−24	− 6	− 17
August .	− 8	+14	+12	−29	+ 12	− 5	+ 4	−11	−25	−13	− 7	−21	− 3
Summer .	−59	−26	−35	−79	− 3	−59	−40	−91	−53	−86	−79	−66	− 8
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm
September .	+20	+ 8	+32	+ 2	+ 18	+35	+21	+25	+ 3	+ 6	+24	+38	− 2
October .	− 4	−28	+ 4	+ 3	− 2	+ 9	−14	+11	−17	+ 4	−20	−19	− 1
November .	−27	+ 9	−32	−30	− 8	−18	+ 3	−28	−33	−82	+ 1	−44	− 8
Autumn .	−11	−11	+ 4	−25	+ 8	+26	+10	+ 8	−47	−72	+ 5	−25	−10
YEAR. Dec.—Nov.	+25	+86	+84	+70	+116	+ 39	−15	+ 9	0	−32	−39	+28	− 5

Daily Mean Sunshine.

1924.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs
December .	+0.09	+0.62	+0.01	+0.04	+0.33	+0.04	+0.09	+0.15	+0.05	−0.09	−0.03	+0.31	+0.1
1925.													
January .	−0.05	−0.07	−0.41	−0.03	+0.09	−0.23	−0.10	−0.03	+0.22	−0.23	+0.04	+0.15	+0.2
February .	−0.04	+0.61	+0.18	+0.37	+0.08	+0.03	−0.22	−0.23	+0.14	−0.54	+0.05	−0.25	−0.0
Winter .	0.00	+0.39	−0.07	+0.13	+0.17	−0.05	−0 08	−0.04	+0.14	−0.29	+0.02	+0.07	+0.0
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs
March .	−0.23	+0.26	−0.05	+0.09	−0.16	−0.83	−0.88	−0.13	−0.27	+0.44	−0.54	+0.03	−0.4
April .	+0.01	−0.04	+0.23	+0.18	−0.73	−0.02	−1.05	+0.58	+0.92	+0.78	−0.51	+0.27	+0.0
May .	−1.22	−1.78	−1.74	−2.49	+0.35	−0.92	+0.46	−1.84	−2.05	−2.04	−0.59	−1.30	−0.0
Spring .	−0.48	−0.52	−0.52	−0.74	−0.18	−0.79	−0.49	−0.46	−0.47	−0.27	−0.55	−0.33	−0.1
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs
June . .	+2.10	+4.25	+4.26	+2.19	+2.45	+1.82	+1.38	+2.52	+1.44	+2.94	+0.65	+1.34	−0.2
July . .	−0.32	−1.10	−0.52	−1.39	−0.21	−0.09	−0.24	+0.04	−1.17	+0.05	+0.01	−0.32	−0.0
August .	−0.61	−1.92	−1.01	−0.11	−1.12	−1.34	−1.20	−0.60	+0.54	−0.26	−0.78	−0.18	−0.0
Summer .	+0.39	+0.41	+0.91	+0.23	+0.37	+0.13	−0.02	+0.65	+0.27	+0.58	−0.04	+0.49	−0.1
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs
September .	−0.48	−0.35	−0.04	−0.62	−0.65	−0.48	−1.25	−0.36	−0.66	+0.52	−0.88	−0.40	−1.
October .	−0.04	+0.27	+0.07	−0.58	−0.30	−0.13	0.00	−0.33	−0.52	−0.05	+0.28	+0.53	−0.
November .	+0.96	+0.25	+1.03	+1.05	+0.95	+0.77	+0.65	+1.40	+0.82	+1.25	+0.73	+0.99	+0.3
Autumn .	+0.15	+0.06	+0.35	−0.03	+0.20	+0.05	−0.20	+0.24	−0.12	+0.57	+0.04	−0.37	−0.
YEAR Dec.—Nov.	hrs. +0.02	hrs. +0.11	hrs. +0.17	hrs. −0.10	hrs. +0.14	hrs. +0.14	hrs. −0.20	hrs. +0.10	hrs. −0.05	hrs. +0.15	hrs. −0.13	hrs. −0 03	hrs −0
	Br. Isl. Mean A—J.	Ch. Is'ds	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K

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TABLE II.—Variation from the Average of Successive Fortnights above and below 42° F. 1881-1915 (Year 1915).

Months (to nearest weeks).	Mean A	Channel Islands 11	Eng. N.W. 8	Ire. S. 10	Eng. S.E. 5	Eng. Mid. 4	Eng. E. 3	Eng. N.W. 7	Ire. N. 9	Sco. W. 6	Eng. N.E. 2	Sco. E. 1	Sco. N. 0
	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°	above / below 42°
Nov. 30—Dec. 27	+ 62 — 76	+ 35 — 15	+ 61 — 55	+ 76 — 54	+ 44 — 56	+ 49 — 99	+ 44 — 75	+ 82 — 83	+ 76 — 71	+ 77 — 74	+ 53 — 88	+ 59 — 109	+ 71 — 98
Dec. 28—Jan. 31	+ 24 — 79	+ 44 — 30	+ 40 — 73	+ 29 — 49	+ 39 — 89	+ 14 — 98	+ 32 — 106	+ 23 — 81	+ 30 — 63	+ 19 — 67	+ 10 — 79	+ 1 — 76	+ 16 — 83
Feb. 1—Feb. 28	+ 2 — 35	+ 22 — 22	+ 15 — 38	— 12 — 10	+ 21 — 50	+ 12 — 51	+ 17 — 61	+ 2 — 36	— 14 — 15	— 6 — 24	+ 2 — 37	— 19 — 34	— 5 — 40
Winter . .	+ 88 — 190	+ 101 — 76	+ 116 — 166	+ 93 — 113	+ 104 — 195	+ 75 — 248	+ 93 — 242	+ 107 — 200	+ 92 — 149	+ 90 — 165	+ 65 — 204	+ 41 — 219	+ 82 — 221
Actual Aggregates	233 155	450 12	320 75	344 96	266 131	200 195	210 183	237 120	255 120	211 156	165 194	122 275	166 191
Mar. 1—Mar. 28	— 10 — 12	— 24 — 2	— 9 + 4	— 5 — 10	— 12 + 1	— 20 — 12	— 24 — 18	— 14 — 20	0 — 24	+ 9 — 8	— 12 — 14	— 10 — 19	— 4 — 27
Mar. 29—May 2	— 20 — 7	— 26 — 7	— 20 — 7	— 32 + 1	— 27 0	— 20 — 11	— 10 — 25	— 16 — 17	— 27 0	— 18 — 1	— 2 — 14	— 34 0	— 9 — 19
May 3—May 30	+ 37 — 10	+ 4 0	+ 19 — 4	— 23 — 3	+ 48 — 5	+ 65 — 14	+ 102 — 11	+ 49 — 7	— 14 — 7	+ 19 — 12	+ 85 — 11	+ 22 — 26	+ 37 — 24
Spring . .	+ 7 — 29	— 46 — 9	— 10 — 7	— 60 — 12	+ 9 — 4	+ 25 — 37	+ 68 — 54	+ 19 — 44	— 41 — 31	+ 10 — 21	+ 71 — 39	— 22 — 45	+ 24 — 70
Actual Aggregates	471 139	583 25	504 110	481 90	552 135	531 173	562 136	457 106	400 107	421 154	468 153	334 222	327 172
May 31—June 27	+ 46 0	+ 72 0	+ 71 0	+ 57 0	+ 60 0	+ 55 0	+ 44 0	+ 46 0	+ 19 0	+ 46 0	+ 25 0	+ 40 — 2	+ 39 — 2
June 28—Aug. 1	+ 53 0	+ 10 0	+ 38 0	+ 17 0	+ 37 0	+ 76 0	+ 58 0	+ 66 0	+ 17 0	+ 75 0	+ 80 0	+ 62 0	+ 91 0
Aug. 2—Aug. 29	+ 10 0	— 12 0	+ 13 0	+ 6 0	— 12 0	+ 13 0	+ 18 0	+ 12 0	+ 6 0	+ 17 0	+ 21 0	+ 3 0	+ 14 0
Summer . .	+ 109 0	+ 70 0	+ 122 0	+ 80 0	+ 85 0	+ 144 0	+ 120 0	+ 124 0	+ 42 0	+ 138 0	+ 126 0	+ 105 — 2	+ 144 — 2
Actual Aggregates	1529 0	1700 0	1621 0	1528 0	1701 0	1640 0	1672 0	1540 0	1343 0	1434 0	1504 0	1308 0	1222 0
Aug. 30—Oct. 3	— 77 0	— 84 0	— 73 0	— 62 0	— 99 0	— 77 — 2	— 81 0	— 77 0	— 63 0	— 72 — 1	— 83 0	— 88 0	— 60 — 2
Oct. 4—Oct. 31	+ 28 — 8	+ 32 0	+ 37 — 5	+ 56 — 11	+ 26 — 5	+ 29 — 10	+ 27 — 6	+ 27 — 9	+ 46 — 12	+ 16 — 6	+ 17 0	— 1 — 9	— 3 — 1
Nov. 1—Nov. 28	— 53 + 63	— 87 + 12	— 73 + 65	— 65 + 52	— 57 + 60	— 48 + 77	— 34 + 38	— 60 + 91	— 41 + 27	— 51 + 70	— 49 + 85	— 44 + 63	— 35 + 30
Autumn . .	— 102 + 55	— 139 + 12	— 109 + 60	— 71 + 41	— 130 + 55	— 96 + 65	— 88 + 32	— 110 + 82	— 58 + 15	— 107 + 63	— 115 + 85	— 133 + 54	— 98 + 27
Actual Aggregates	692 115	1041 15	800 95	786 84	816 100	677 148	767 94	681 129	685 64	596 128	636 142	478 166	486 111
YEAR.													
Nov. 30—Nov. 28	+ 102 — 156	— 14 — 73	+ 119 — 113	+ 42 — 84	+ 68 — 144	+ 148 — 222	+ 193 — 264	+ 140 — 162	+ 35 — 165	+ 131 — 123	+ 147 — 158	— 11 — 212	+ 152 — 266
Actual Aggregates	2925 409	3774 52	3245 280	3139 270	3335 366	3048 516	3211 413	2915 355	2683 291	2662 438	2773 489	2242 663	2201 474

The "Actual Aggregates" are the totals for the periods in question of degrees of daily mean temperature respectively above and below 42° F.

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TABLE II.—List of New Stations furnishing Plant, Bird, and Insect Records, with the Names of the Observers.

The numbers in brackets following the District Letters represent the Meteorological Office designations.

The stations listed below have not reported for 1925. * indicates that the observer has changed his residence and is continuing to observe at a new station.

A 2b, 8b, *10a, 11b, 12a, 13b, 13d, 16a, *16b, 21b, 19a, *28a, 34a, 5e, 5f, 8c, 14c, 17c, 18c, 29c. B 34a, 34e. C *9a, 16f, 16h, 20b, 14a, *18d, 22d, 29a, 12a, 16j, 17b, 24c, 26e. D 16a, 15b, 21c, 37a, 3c, 24c, 44c. E 1a, 1b, 4a, 4d, 7a, 7c, 7d, 8d, 3a, 10c, 14b, 11a, 23b, 21a, 27c, 28a, 1c, 10e, 22a. F *1a, 28a, 11f. G *12a, *35b, 50b, *41b, *50e, 46a. H 8b. I 11a, 28a, 24a, 5a. J *18a, 16a, 22a, 42a, 13b, 40a. K *27a.

The following stations absent in 1924 have now returned: A 24d, 19c, 32b, 43b. B 22a. C 20c, 24b. D 5a. E 8c, 17a. F 22c. G 50d. H 27b. I 8a. J 35b. These are included in the *numbers* of additional stations shown below, but are not listed here, full details having been given in the 1923 Report.

The station previously listed as Alton, C 16e, should be described as Newton Valence, Alton, and is accordingly re-numbered C 11b.

Station.	County.	Height above Sea-level.	Observer.
A (8).			Observers: 77−20+16=73.
1b. St. Buryan	Cornwall	200	Miss E. Westrup.
2f. Phillack Hayle	Cornwall	100	F. Harris.
6c. Lopwell, Plymouth *	Devon		W. H. Fowler.
11e. Bridestowe	Devon	900	J. M. Loveband.
12c. Bradworthy	Devon	700	Comdr. G. Corlett & Friends.
12d. Appledore	Devon	100	Miss L. E. Richards.
17d. Combe Martin	Devon	250	S. Laurence.
17e. Ilfracombe	Devon	100	Miss M. J. Shute.
21d. Broadstone	Dorset	310	Mrs. I. M. Bingham.
19f. Taunton	Somerset	0	Misses F. E. & E. R. Welch.
19g. West Buckland, Wellington	Somerset	210	E. B. Bellamy.
28d. Llandaff	Glamorgan	100	Miss C. M. Acland.
B (10).			Observers: 15−2+4=17.
27a. Castleconnell	Co. Limerick	170	J. E. Austin.
38a. Borris	Co. Carlow	700	Mrs. C. Butler.
42a. Ballickmoyler	Queen's Co.	240	Mrs. A. M. Irwin.
C (5).			Observers: 64−13+9=60.
3f. Southsea	Hants	0	E. Field.
4d. Minstead, Lyndhurst	Hants	300	Miss J. Case.
16k. Yateley	Hants	(300)	Miss Stillwell.
15d. Horsham	Sussex	160	Mrs. T. Faulkner Jeffries.
16l. Thursley	Surrey	(350)	A. H. Macpherson.
25c. Maidstone	Kent	(150)	M. E. Lucy.
28a. Rochester	Kent	120	Mrs. H. M. Rait Kerr, B.E.N.A.
D (4).			Observers: 62−7+9=64.
5d. Coaley	Gloucester	300	A. D. Norton, B.E.N.A.
11b. Ludlow	Salop	300	A. J. Edwards.
11c. Ludlow	Salop	300	J. G. Lang, D.Sc., F.Z.S.
6e. Malvern Hills	Worcester	(800)	J. H. Main.
21f. Hall Green, Birmingham	Warwick	400	T. C. Swain.

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21g. King's Heath, Birmingham	Warwick	520	R. Clarke.
39d. Sheffield	Yorks W.R.	500	A. Thompson.
44d. Mexborough	Yorks W.R.	(200)	G. Middleton.
E (3).			Observers: 46−19+11=38.
4l. Harpenden	Herts	400	A. H. Meiklejohn.
7f. Buntingford	Herts	270	E. E. Dennis.
10f. Great Totham, Maldon	Essex	200	T. Hammond.
11d. Cambridge	Cambridge	50	Miss S. M. Mills.
17b. Ipswich	Suffolk	150	A. G. Glenn.
17c. Ipswich	Suffolk	(150)	W. H. Ramsey.
17d. Bramford, Ipswich	Suffolk	(150)	Mrs. F. Lillie.
22b. Langford, Watton	Norfolk	60	A. H. Turner.
28b. Ingham, Stalham	Norfolk	30	R. Gurney.
F (7).			Observers: 25−3+6=28.
16c. Cheadle Hulme	Cheshire	200	J. W. Hartley.
18a. Blackpool	Lancs	0	E. C. Thatcher.
22d. Grange-over-Sands	Lancs	250	Dr. R. C. Lowther.
25c. Windermere	Westmor.	350	A. B. Reynolds.
31a. Kelsick, Wigton	Cumber.	50	J. Murray.
G (9).			Observers: 18−6+6=18.
18a. Longford	Co. Longford	220	Mrs. W. J. Bond.
32b. Levally, Enniskillen	Co. Ferma.	280	Rev. W. B. Steele.
47a. Sixtowns, Draperstown	Co. Derry	400	G. Barnett.
41c. Scarva	Co. Down	340	W. Armstrong.
50f. Woodburn, Belfast	Co. Down	100	Miss N. M. Neill.
H (6).			Observers: 6−1+1=6.
I (2).			Observers: 26−4+14=36.
11d. Cleethorpes	Lincs	40	Miss A. F. Oddy, M.Sc.
13a. Osgodby, Selby	Yorks E.R.	30	J. W. Eves.
32b. Nunthorpe	Yorks E.R.	500	Mrs. Hamilton.
18a. Middleton-in-Teesdale	Durham	800	J. J. Parker.
24b. Darlington	Durham	170	Darlington and Teesdale Naturalists' Field Club.
25c. Corbridge	Durham	500	R. B. Cooke.
33c. Chester-le-Street	Durham	40	J. Baxter.
33d. Gateshead	Durham	550	G. H. Anderson.
33e. South Shields	Durham	10	W. Bennett.
33f. North Shields	Northumb.		J. B. Spence.
25d. Allendale	Northumb.	900	G. Stephenson.
38c. Lemmington, Alnwick	Northumb.	750	F. E. Lupton.
39a. Berwick-on-Tweed	Northumb.	50	J. B. Duncan.
J (1).			Observers: 20−6+3=17.
10b. Duns	Berwick	410	Senior Scholars, Duns School.
15a. Dunfermline	Fife	400	N. M. Johnson, B.Sc., L.C.P., F.R.S.G.S.
K (0).			Observers: 5−1+1=5.
27b. Kirkhill, Muir of Ord	Inverness	450	Mrs. V. M. Baird Ferguson.

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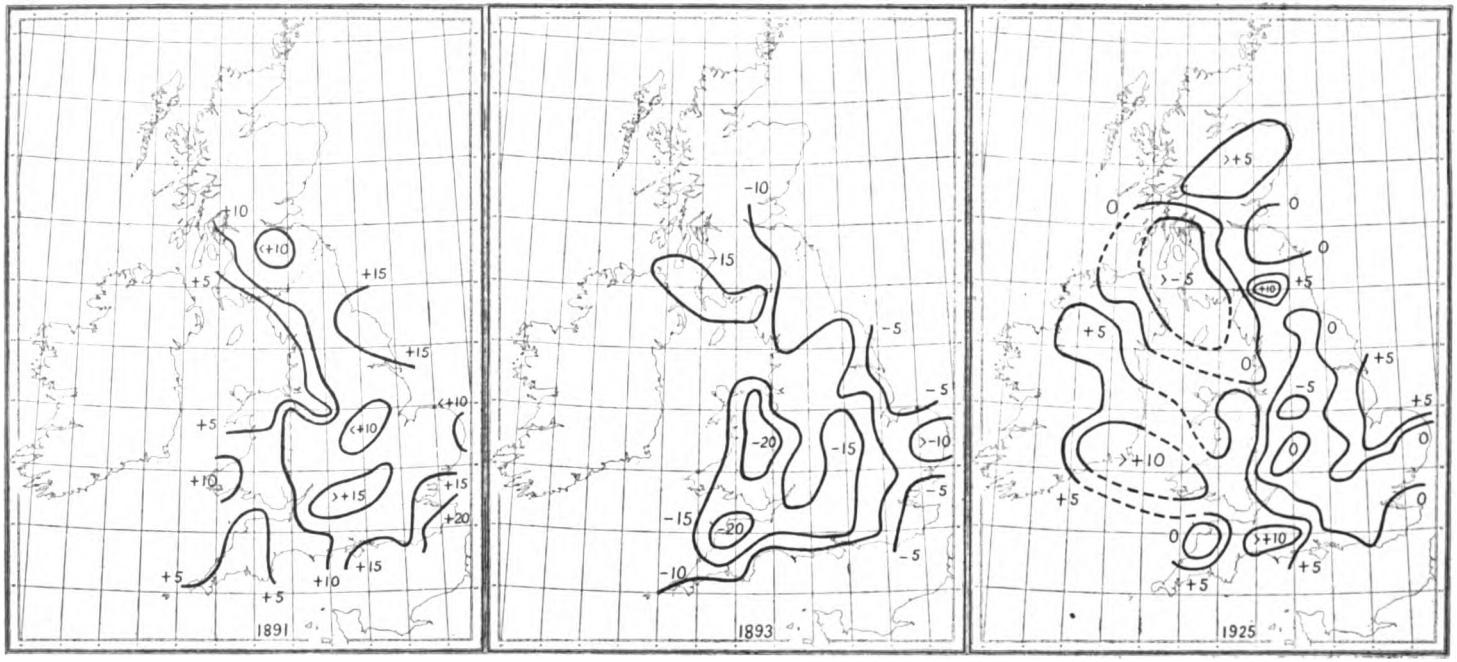

FIG. 4.—Floral Isakairs, or lines of equal divergence (*Gr. isē akairia* equal unseasonableness) from the average flowering date, for the years 1891, 1893 and 1925.

The lines indicate the distribution of differences of 5, 10, 15, and 20 days before (−) or after (+) the average date of the region.

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Cornwall peninsula, while the isakair + 20 days appears over Kent. In 1893, earliness was everywhere, but *decreased* from W to E, giving Central Wales and N. Devon − 20 days, while isakair − 10 days included all the W. Lowlands and all England south of the Tees and west of the line York-Brighton. These two maps appear to indicate the dominating continental influence in extreme years, increasing the lateness in the east in 1891 and neutralising the excess of sea-borne warmth in 1893. Lack of data prevents the extension of the maps to the Highlands and Ireland.

In comparison, the map for 1925 is more complex, due perhaps to the absence of such phenomenal weather conditions as occurred in 1891 and 1893. The main features are a large, late area covering S.E. Ireland, S. Wales, with an extension over Somerset and Dorset, in all of which isakair + 10 days occurs; an early region covering N.E. Ireland and S.W. Scotland; a late area over the Highlands; and another small, late area on the high ground near Carlisle, which also shows isakair + 10. The Midlands, England E and SE showed little departure from normal.

A comparison with the isotherm distribution, Fig. 2, shows natural correspondences. Earliness and warmth stretch from the Cotswolds to S.E. Yorks, and recur near the Firth of Forth and over the S.W. Highlands. Lateness and coolness occur over S. Wilts and E. Dorset, Central Wales, round the Wash, near the Scotch borders, SE from Cork, and over north-central Ireland. But there are one or two slight discrepancies; the north Welsh coast and Aberdeenshire are late and warm.

Fig. 5 brings out in a practical way the unusually small variation from district to district. As a rule it can hardly be compressed into 63 lines. For 1925, 48 lines were ample. Six of the 13 occupy only three lines each: in 1924 the dog rose alone. Among other problems suggested are the contrasts between hazel and coltsfoot, and of black knapweed with greater bindweed and harebell, the periods overlapping in each case.

This figure, with Tables IIIA. and IV., indicates seasonal changes. Over England and Wales, earliness prevailed up to the flowering of the blackthorn in the last week of April, the coltsfoot by as much as 10 days. Lateness ensued, lasting into July, except in England SE, when a return to normal is shown by the dog rose. The final averaging gives a "normal" year. For the whole British Isles the blackthorn itself was normal, and after that date divergence was very small. District lateness reached 7 days in Ireland S, in contrast with the 6 days early of Scotland W.

MR. LOWE'S RECORDS. At the end of Table VIII. we add the difference from the 10 years' average, which he gave us last year for 7 trees. The hazel alone was early in flower, the mean lateness being 5 days. Fruit ripening was 4 days late and autumn colouring early, full tint and bare boughs by nearly a week.

INSECTS OF TABLE VI.—All five, except the last, are later than the 35-year average, most notably the honey bee, nearly a fortnight late in England and Wales, the wasp and orange tip being some weeks later. Turning to districts, we find the bee up to date, February 27, only in England SW, lateness increasing to three weeks in the Midlands, Ireland N, England NE, and to four weeks

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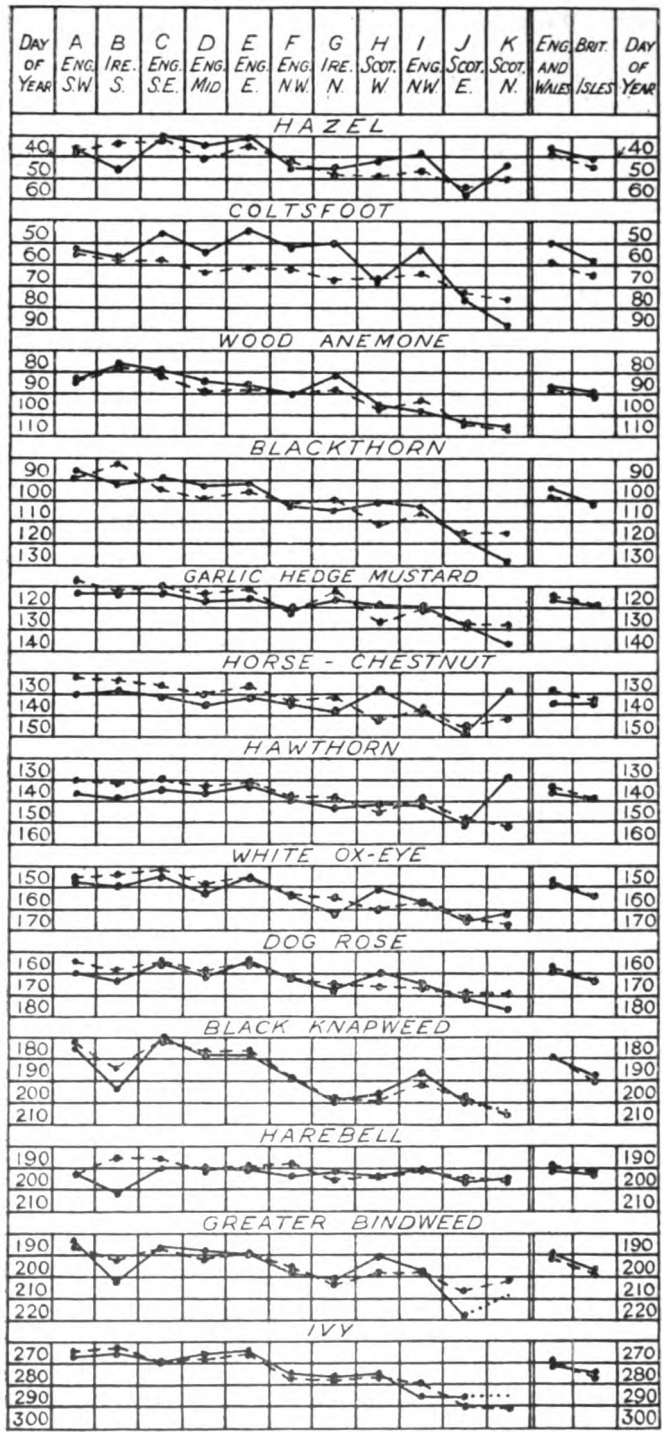

FIG. 5.—Dates of Flowering of Plants by Districts.

1925 ——— 30 years' average --- - --- - Conjectural . . . . .

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(April 2) in England NW. The wasp ranges from 17 days early in Scotland W, to 14 late in England SW. The very abnormal date, seven weeks early in Ireland S, is very doubtful on account of scarcity of observations; another was too precocious, and three far too late. As this leaves three records only, it is none too reliable. Yet it represents the abnormal early winter warmth; *cf.* Table I. In Scotland N the comparative earliness of orange tip and meadow brown may possibly be due to the excess of midsummer daylight. But more stations are necessary in K. to verify such a point.

MIGRANTS (Tables VI., VIA., VII., VIIA., and Fig. 6). Arrival dates in 1925 have been more regular. Only three, and these rarer birds, average over four days late; three only were a little early. Three extra columns in Table VII. show mean arrival dates of the earliest six, the middle 11 and latest 11. The first were most

FIG. 6.—Migrant Isophenes (lines of equal arrival dates) 1925. Based on the 28 birds and 131 stations of the Migrant Table. See Table VII.
Also Isophene Stations 1925: Floral •, Migrant ×, Floral and Migrant ✖

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retarded. We also show their mean values for the districts. Comparison should be made with the migrant isophenes; the whole 28 are a day and a half behind the 10 years' average.

ADDITIONAL SPRING MIGRANTS. Ring ouzel (16 records), 103 or April 13; pied flycatcher (6), 121 or May 1. The records in 1924 were 22 and 21 respectively.

OTHER MIGRANT MOVEMENTS (VIIa.). Nos. 1 to 3 and 5 to 9 average in each case three days early, say, January 31 and September 27. Thus these extensions, giving bird records earlier and later than those shown by the migrant tables, indicate respectively the effect of the winter mildness and the early autumn coolness. Both are confirmed by Table VI. The thrush is eight days early; the departing swallow seven days.

MIGRANT ISOPHENES. These are based on over 3,000 records from 131 stations, practically the same number as last year. The general trend of the isophenes differs little from 1924, but the late areas are more extensive, except at our S and SE coasts. Here isophene 115 extended further inland, while 112 (absent in 1924) appears on a narrow coastal strip—clear indications of earlier arrival subsequently retarded. Elsewhere, lateness is shown by the more southward extension of isophenes 117 and 121 in 1925. In Scotland the isophenes for 1924 and 1925 are almost identical. Lack of data renders Ireland uncertain, but the exceptional earliness indicated south from Belfast over Co. Down can hardly be ignored, for the same characteristic is shown on the maps for both 1923 and 1924. In 1923 isophene 115 occupied almost the same position as is shown now, and in 1924 isophene 118 makes a similar northward loop.

THE SIX BIRDS OF TABLE VI. The mean of the three migrants, recorded in all districts, agrees with the 35-year average. The Table VII. average is for ten years only. This may be comparatively late, perhaps by a day. Hence the difference of one and a half days may, when it can be tested, prove to represent no actual divergence. Graphs worked out by Mr. Marshall of the six birds from district to district, corresponding to Fig. 5 for plants, bring out an interesting relation for the 35 years of the arrival date of the cuckoo compared to the swallow, the two birds for which our returns are most complete and therefore reliable. It is shown yet better by plotting the differences on a map of the districts. The cuckoo comes later as follows:—C and E, 2 days; D, 3; I and J, 5; A, 6; F and H, 7; B and G, 10; but K, −1. In other words, passing westward from the SE, relative lateness grows by 8 days on reaching Ireland; up the N.W. coast, 5 days to the Solway and Scot. W; up the N.E. coast, 3 days to Berwick and Scot. E. In Scot. N the cuckoo actually outflies the swallow and arrives first. Is this, too, associated with the long daylight hours? This was so unexpected that all the 35 years' records have been re-examined and those only selected where both were observed, 65 cases in all. The result is still the same. It is spread over 32 of the 35 years, in 16 of which the cuckoo came first; in 16 the swallow. A comparison with Table V. shows no close association with the flowering, early or late; but that table includes only England and Wales.

(*Continued on page* 297.)

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TABLE I.—VARIATIONS FROM THE AVERAGE IN TEMPERATURE, RAINFALL, AND SUNSHINE, 1924-25.

Daily Mean Temperature.

Terms.	Mean Dis. A—J.	Chan. Islands	A. Eng. S.W.	B. Ire. S.	C. Eng. S.E.	D. Eng. Mid.	E. Eng. E.	F. Eng. N.W.	G. Ire. N.	H. Scot. W.	I. Eng. N.E.	J. Scot. E.	K. Scot. N.
		11.	8.	10.	5.	4.	3.	7.	9.	6.	2.	1.	0.
1924	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
December .	+4.3	+1.3	+3.6	+3.6	+3.2	+4.6	+3.8	+5.2	+4.2	+4.7	+4.4	+5.2	+5.2
1925.													
January .	+3.1	+2.5	+3.3	+2.8	+3.5	+3.2	+3.7	+3.0	+3.1	+2.9	+2.5	+2.5	+3.5
February .	+1.3	−1.6	+1.8	0.0	+2.4	+2.1	+2.7	+2.3	−0.1	+0.5	+1.5	+0.3	+0.4
Winter .	+2.9	+1.8	+2.9	+2.1	+3.0	+3.3	+3.4	+3.2	+2.4	+2.7	+2.8	+2.7	+3.0
March .	−0.1	−1.1	−0.9	−0.1	−0.9	−0.4	−0.4	−0.1	+0.7	+0.6	0.0	−0.1	+0.6
April .	−0.8	−0.7	−0.5	−1.2	−1.1	−0.6	−0.1	−0.6	−1.3	−1.1	−0.3	−1.5	0.0
May .	+0.6	−0.7	−0.2	−1.3	+0.9	+1.5	+2.7	+0.8	−1.0	+0.2	+2.2	+0.5	+1.2
Spring .	−0.1	−0.8	−0.5	−0.9	−0.4	+0.2	+0.8	0.0	−0.5	−0.1	+0.6	−0.4	+0.6
June .	−1.2	+2.1	+2.4	+1.8	+1.4	+1.5	+0.6	+1.2	+0.5	+1.4	+0.3	+1.1	+1.3
July .	+1.6	+0.3	+1.2	+0.4	+1.3	+2.3	+2.1	+2.0	+0.3	+2.3	+2.4	+1.8	+3.0
August .	+0.7	−0.4	+0.7	+0.5	−0.2	+0.9	+0.8	+1.0	+0.5	+0.9	+1.0	+0.4	+0.9
Summer .	+1.2	+0.7	+1.4	+0.9	+0.8	+1.6	+1.2	+1.4	+0.4	+1.5	+1.2	+1.1	+1.7
September .	−2.6	−2.7	−2.4	−1.8	−3.5	−2.7	−2.8	−2.5	−2.0	−2.3	−2.6	−3.0	−2.1
October .	+1.9	+1.7	+2.2	+2.6	+1.9	+2.2	+2.2	+1.6	+2.5	+1.6	+1.4	+1.3	+1.2
November .	−3.8	−3.1	−4.5	−3.7	−3.9	−4.2	−2.3	−5.3	−2.1	−3.9	−4.4	−3.5	−1.7
Autumn .	−1.5	−1.4	−1.6	−1.0	−1.8	−1.6	−1.0	−2.1	−0.5	−1.5	−1.9	−1.7	−0.9
Year. Dec.–Nov.	+0.6	+0.1	+0.6	+0.3	+0.4	+0.9	+1.1	+0.6	+0.7	+0.7	+0.7	+0.4	+1.1

+ indicates above the average, − below it.

Total Rainfall.

[25 millimetres practically equal 1 inch; hence 0.04 inch equals 1 mm.]

	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1924 December .	+21	− 3	+22	+ 59	+25	+17	+ 7	+24	+24	+27	− 4	+14	+58
1925. January .	+ 2	+43	+13	+ 40	+24	− 1	−14	−12	− 3	− 8	−11	− 4	− 4
February .	+41	+35	+62	+ 49	+50	+33	+18	+62	+40	+14	+23	+49	+24
Winter .	+64	+75	+97	+148	+99	+54	+11	+74	+61	+33	+ 8	+59	+78
March .	−32	−42	−54	−65	−35	−29	−11	−36	−36	−36	−12	− 4	−11
April .	+22	+37	+15	+ 34	+17	+ 7	+10	+11	+30	+49	+21	+28	+22
May .	+41	+53	+57	+ 57	+30	+40	+ 5	+43	+45	+80	+18	+36	+41
Spring .	+31	+48	+18	+26	+12	+18	+ 4	+18	+39	+93	+27	+60	+52

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TABLE I.—VARIATIONS FROM THE AVERAGE—*continued.*

Total Rainfall—continued.

MONTHS.	Mean Dis. A—J.	Chan. Islands. 11.	A. Eng. S.W 8.	B. Ire. S. 10.	C. Eng. S.E. 5.	D. Eng. Mid. 4.	E. Eng. E. 3.	F. Eng. N.W. 7.	G. Ire. N. 9.	H. Scot. W. 6.	I. Eng. N.E. 2.	J. Scot. E. 1.	
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm
June . .	−50	−45	−57	−56	− 45	−54	−39	−58	−50	−51	−48	−39	—
July . .	− 1	+ 5	+10	+ 6	+ 30	0	− 5	−22	+22	−22	−24	− 6	—
August .	− 8	+14	+12	−29	+ 12	− 5	+ 4	−11	−25	−13	− 7	−21	—
Summer .	−59	−26	−35	−79	− 3	−59	−40	−91	−53	−86	−79	−66	—
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	m
September .	+20	+ 8	+32	+ 2	+ 18	+35	+21	+25	+ 3	+ 6	+24	+38	—
October .	− 4	−28	+ 4	+ 3	− 2	+ 9	−14	+11	−17	+ 4	−20	−19	—
November .	−27	+ 9	−32	−30	− 8	−18	+ 3	−28	−33	−82	+ 1	−44	—
Autumn .	−11	−11	+ 4	−25	+ 8	+26	+10	+ 8	−47	−72	+ 5	−25	—
YEAR. Dec.—Nov.	+25	+86	+84	+70	+116	+ 39	−15	+ 9	0	−32	−39	+28	—

Daily Mean Sunshine.

1924.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	h
December .	+0.09	+0.62	+0.01	+0.04	+0.33	+0.04	+0.09	+0.15	+0.05	−0.09	−0.03	+0.31	+
1925.													
January .	−0.05	−0.07	−0.41	−0.03	+0.09	−0.23	−0.10	−0.03	+0.22	−0.23	+0.04	+0.15	+
February .	−0.04	+0.61	+0.18	+0.37	+0.08	+0.03	−0.22	−0.23	+0.14	−0.54	+0.05	−0.25	−
Winter .	0.00	+0.39	−0.07	+0.13	+0.17	−0.05	−0 08	−0.04	+0.14	−0.29	+0.02	+0.07	+
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	h
March .	−0.23	+0.26	−0.05	+0.09	−0.16	−0.83	−0.88	−0.13	−0.27	+0.44	−0.54	+0.03	−
April .	+0.01	−0.04	+0.23	+0.18	−0.73	−0.02	−1.05	+0.58	+0.92	+0.78	−0.51	+0.27	+
May .	−1.22	−1.78	−1.74	−2.49	+0.35	−0.92	+0.46	−1.84	−2.05	−2.04	−0.59	−1.30	−
Spring .	−0.48	−0.52	−0.52	−0.74	−0.18	−0.79	−0.49	−0.46	−0.47	−0.27	−0.55	−0.33	−
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	h
June . .	+2.10	+4.25	+4.26	+2.19	+2.45	+1.82	+1.38	+2.52	+1.44	+2.04	+0.65	+1.34	+
July . .	−0.32	−1.10	−0.52	−1.39	−0.21	−0.09	−0.24	+0.04	−1.17	+0.05	+0.01	+0.32	−
August .	−0.61	−1.02	−1.01	−0.11	−1.12	−1.34	−1.20	−0.60	+0.54	−0.26	−0.78	−0.18	−
Summer .	+0.39	+0.41	+0.91	+0.23	+0.37	+0.13	−0.02	+0.65	+0.27	+0.58	−0.04	+0.49	+
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	h
September .	−0.48	−0.35	−0.04	−0.62	−0.65	−0.48	−1.25	−0.36	−0.66	+0.52	−0.88	−0.40	−
October .	−0.04	+0.27	+0.07	−0.58	−0.30	−0.13	0.00	−0.33	−0.52	−0.05	+0.28	+0.53	−
November .	+0.96	+0.25	+1.03	+1.05	+0.95	+0.77	+0.65	+1.40	+0.82	+1.25	+0.73	+0.69	−
Autumn .	+0.15	+0.06	+0.35	−0.03	+0.20	+0.05	−0.20	+0.24	−0.12	+0.57	+0.04	−0.37	−
YEAR Dec.—Nov.	hrs. +0.02	hrs. +0.11	hrs. +0.17	hrs. −0.10	hrs. +0.14	hrs. +0.14	hrs. −0.20	hrs. +0.10	hrs. −0.05	hrs. +0.15	hrs. −0.13	hrs. −0.03	h −
	Br. Isl. Mean A—J.	Ch. Is'ds	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	

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TABLE Ia.—Variation from the Average in Accumulated Temperature above and below 42° F., 1924-1925 (Day—Deg. F.).

Months (to nearest weeks).	Mean. A—J.		Channel Islands. 11.		A. Eng. S.W. 8.		B. Ire. S. 10.		C. Eng. S.E. 5.		D. Eng. Mid. 4.		E. Eng. E. 3.		F. Eng. N.W. 7.		G. Ire. N. 9		H. Scot. W. 6.		I. Eng. N.E. 2.		J. Scot E. 1.		K. Scot. N. 0.	
	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°	above 42°	below 42°
Nov. 30—Dec. 27	+ 62	— 76	+ 35	— 15	+ 61	— 55	+ 76	— 54	+ 44	— 56	+ 49	— 99	+ 44	— 75	+ 82	— 83	+ 76	— 71	+ 77	— 74	+ 53	— 88	+ 59	—109	+ 71	— 98
Dec. 28—Jan. 31	+ 24	— 79	+ 44	— 39	+ 40	— 73	+ 29	— 49	+ 39	— 89	+ 14	— 98	+ 32	—106	+ 23	— 81	+ 30	— 63	+ 19	— 67	+ 10	— 79	+ 1	— 76	+ 16	— 83
Feb. 1—Feb. 28	+ 2	— 35	+ 22	— 22	+ 15	— 38	— 12	— 10	+ 21	— 50	+ 12	— 51	+ 17	— 61	+ 2	— 36	— 14	— 15	— 6	— 24	+ 2	— 37	— 19	— 34	— 5	— 40
Winter	+ 88	—190	+101	— 76	+116	—166	+ 93	—113	+104	—195	+ 75	—248	+ 93	—242	+107	—200	+ 92	—149	+ 90	—165	+ 65	—204	+ 41	—219	+ 82	—221
Actual Aggregates	233	155	450	12	320	75	344	96	266	131	200	195	210	183	237	120	255	120	211	156	165	194	122	275	166	191
Mar. 1—Mar. 28	— 10	— 12	— 24	— 2	— 9	+ 4	— 5	— 10	— 12	+ 1	— 20	— 12	— 24	— 18	— 14	— 20	0	— 24	+ 9	— 8	— 12	— 14	— 10	— 19	— 4	— 27
Mar. 29—May 2	— 20	— 7	— 26	— 7	— 20	— 7	— 32	+ 1	— 27	0	— 20	— 11	— 10	— 25	— 16	— 17	— 27	0	— 18	— 1	— 2	— 14	— 34	0	— 9	— 19
May 3—May 30	+ 37	— 10	+ 4	0	+ 19	— 4	— 23	— 3	+ 48	— 5	+ 65	— 14	+102	— 11	+ 49	— 7	— 14	— 7	+ 19	— 12	+ 85	— 11	+ 22	— 26	+ 37	— 24
Spring	+ 7	— 29	— 46	— 9	— 10	— 7	— 60	— 12	+ 9	— 4	+ 25	— 37	+ 68	— 54	+ 19	— 44	— 41	— 31	+ 10	— 21	+ 71	— 39	— 22	— 45	+ 24	— 70
Actual Aggregates	471	139	583	25	504	110	481	90	552	135	531	173	562	136	457	106	400	107	421	154	468	153	334	222	327	172
May 31—June 27	+46	0	+ 72	0	+ 71	0	+ 57	0	+ 60	0	+ 55	0	+ 44	0	+ 46	0	+ 19	0	+ 46	0	+ 25	0	+ 40	— 2	+ 39	— 2
June 28—Aug. 1	+53	0	+ 10	0	+ 38	0	+ 17	0	+ 37	0	+ 76	0	+ 58	0	+ 66	0	+ 17	0	+ 75	0	+ 80	0	+ 62	0	+ 91	0
Aug. 2—Aug. 29	+10	0	— 12	0	+ 13	0	+ 6	0	— 12	0	+ 13	0	+ 18	0	+ 12	0	+ 6	0	+ 17	0	+ 21	0	+ 3	0	+ 14	0
Summer	+109	0	+ 70	0	+122	0	+ 80	0	+ 85	0	+144	0	+120	0	+124	0	+ 42	0	+138	0	+126	0	+105	— 2	+144	— 2
Actual Aggregates	1529	0	1700	0	1621	0	1528	0	1701	0	1640	0	1672	0	1540	0	1343	0	1434	0	1504	0	1308	0	1222	0
Aug. 30—Oct. 3	— 77	0	— 84	0	— 73	0	— 62	0	— 99	0	— 77	— 2	— 81	0	— 77	0	— 63	0	— 72	— 1	— 83	0	— 88	0	— 60	— 2
Oct. 4—Oct. 31	+ 28	— 8	+ 32	0	+ 37	— 5	+ 56	— 11	+ 26	— 5	+ 29	— 10	+ 27	— 6	+ 27	— 9	+ 46	— 12	+ 16	— 6	+ 17	0	— 1	— 9	— 3	— 1
Nov. 1—Nov. 28	— 53	+ 63	— 87	+ 12	— 73	+ 65	— 65	+ 52	— 57	+ 60	— 48	+ 77	— 34	+ 38	— 60	+ 91	— 41	+ 27	— 51	+ 70	— 49	+ 85	— 44	+ 63	— 35	+ 30
Autumn	—102	+ 55	—139	+ 12	—109	+ 60	— 71	+ 41	—130	+ 55	— 96	+ 65	— 88	+ 32	—110	+ 82	— 58	+ 15	—107	+ 63	—115	+ 85	—133	+ 54	— 98	+ 27
Actual Aggregates	692	115	1041	15	800	95	786	84	816	100	677	148	767	94	681	129	685	64	596	128	636	142	478	166	486	111
YEAR. Nov. 30—Nov. 28	+102	—156	— 14	— 73	+119	—113	+ 42	— 84	+ 68	—144	+148	—222	+193	—264	+140	—162	+ 35	—165	+131	—123	+147	—158	— 11	—212	+152	—266
Actual Aggregates	2925	409	3774	52	3245	280	3139	270	3335	366	3048	516	3211	413	2915	355	2683	291	2662	438	2773	489	2242	663	2201	474

The "Actual Aggregates" are the totals for the periods in question of degrees of daily mean temperature respectively above and below 42° F.

TABLE II.—List of New Stations furnishing Plant, Bird, and Insect Records, with the Names of the Observers.

The numbers in brackets following the District Letters represent the Meteorological Office designations.

The stations listed below have not reported for 1925. * indicates that the observer has changed his residence and is continuing to observe at a new station.

A 2b, 8b, *10a, 11b, 12a, 13b, 13d, 16a, *16b, 21b, 19a, *28a, 34a, 5e, 5f, 8c, 14c, 17c, 18c, 29c. B 34a, 34e. C *9a, 16f, 16h, 20b, 14a, *18d, 22d, 29a, 12a, 16j, 17b, 24c, 26e. D 16a, 15b, 21c, 37a, 3c, 24c, 44c. E 1a, 1b, 4a, 4d, 7a, 7c, 7d, 8d, 3a, 10c, 14b, 11a, 23b, 21a, 27c, 28a, 1c, 10e, 22a. F *1a, 28a, 11f. G *12a, *35b, 50b, *41b, *50e, 46a. H 8b. I 11a, 28a, 24a, 5a. J *18a, 16a, 22a, 42a, 13b, 40a. K *27a.

The following stations absent in 1924 have now returned: A 24d, 19c, 82b, 43b. B 22a. C 20c, 24b. D 5a. E 8c, 17a. F 22c. G 50d. H 27b. I 8a. J 35b. These are included in the *numbers* of additional stations shown below, but are not listed here, full details having been given in the 1923 Report.

The station previously listed as Alton, C 16e, should be described as Newton Valence, Alton, and is accordingly re-numbered C 11b.

Station.	County.	Height above Sea-level.	Observer.
A (8).			Observers: 77−20+16=73.
1b. St. Buryan	Cornwall	200	Miss E. Westrup.
2f. Phillack Hayle	Cornwall	100	F. Harris.
6c. Lopwell, Plymouth	Devon		W. H. Fowler.
11e. Bridestowe	Devon	900	J. M. Loveband.
12c. Bradworthy	Devon	700	Comdr. G. Corlett & Friends.
12d. Appledore	Devon	100	Miss L. E. Richards.
17d. Combe Martin	Devon	250	S. Laurence.
17e. Ilfracombe	Devon	100	Miss M. J. Shute.
21d. Broadstone	Dorset	310	Mrs. I. M. Bingham.
19f. Taunton	Somerset	0	Misses F. E. & E. R. Welch.
19g. West Buckland, Wellington	Somerset	210	E. B. Bellamy.
28d. Llandaff	Glamorgan	100	Miss C. M. Acland.
B (10).			Observers: 15−2+4=17.
27a. Castleconnell	Co. Limerick	170	J. E. Austin.
38a. Borris	Co. Carlow	700	Mrs. C. Butler.
42a. Ballickmoyler	Queen's Co.	240	Mrs. A. M. Irwin.
C (5).			Observers: 64−13+9=60.
3f. Southsea	Hants	0	E. Field.
4d. Minstead, Lyndhurst	Hants	300	Miss J. Case.
16k. Yateley	Hants	(300)	Miss Stillwell.
15d. Horsham	Sussex	160	Mrs. T. Faulkner Jeffries.
16l. Thursley	Surrey	(350)	A. H. Macpherson.
25c. Maidstone	Kent	(150)	M. E. Lucy.
28a. Rochester	Kent	120	Mrs. H. M. Rait Kerr, B.E.N.A.
D (4).			Observers: 62−7+9=64.
5d. Coaley	Gloucester	300	A. D. Norton, B.E.N.A.
11b. Ludlow	Salop	300	A. J. Edwards.
11c. Ludlow	Salop	300	J. G. Lang, D.Sc., F.Z.S.
6e. Malvern Hills	Worcester	(800)	J. H. Main.
21f. Hall Green, Birmingham	Warwick	400	T. C. Swain.

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21g. King's Heath, Birmingham	Warwick	520	R. Clarke.
39d. Sheffield	Yorks W.R.	500	A. Thompson.
44d. Mexborough	Yorks W.R.	(200)	G. Middleton.
E (3).			Observers: 46−19+11=38.
4l. Harpenden	Herts	400	A. H. Meiklejohn.
7f. Buntingford	Herts	270	E. E. Dennis.
10f. Great Totham, Maldon	Essex	200	T. Hammond.
11d. Cambridge	Cambridge	50	Miss S. M. Mills.
17b. Ipswich	Suffolk	150	A. G. Glenn.
17c. Ipswich	Suffolk	(150)	W. H. Ramsey.
17d. Bramford, Ipswich	Suffolk	(150)	Mrs. F. Lillie.
22b. Langford, Watton	Norfolk	60	A. H. Turner.
28b. Ingham, Stalham	Norfolk	30	R. Gurney.
F (7).			Observers: 25−3+6=28.
16c. Cheadle Hulme	Cheshire	200	J. W. Hartley.
18a. Blackpool	Lancs	0	E. C. Thatcher.
22d. Grange-over-Sands	Lancs	250	Dr. R. C. Lowther.
25c. Windermere	Westmor.	350	A. B. Reynolds.
31a. Kelsick, Wigton	Cumber.	50	J. Murray.
G (9).			Observers: 18−6+6=18.
18a. Longford	Co. Longford	220	Mrs. W. J. Bond.
32b. Levally, Enniskillen	Co. Ferma.	280	Rev. W. B. Steele.
47a. Sixtowns, Draperstown	Co. Derry	400	G. Barnett.
41c. Scarva	Co. Down	340	W. Armstrong.
50f. Woodburn, Belfast	Co. Down	100	Miss N. M. Neill.
H (6).			Observers: 6−1+1=6.
I (2).			Observers: 26−4+14=36.
11d. Cleethorpes	Lincs	40	Miss A. F. Oddy, M.Sc.
13a. Osgodby, Selby	Yorks E.R.	30	J. W. Eves.
32b. Nunthorpe	Yorks E.R.	500	Mrs. Hamilton.
18a. Middleton-in-Teesdale	Durham	800	J. J. Parker.
24b. Darlington	Durham	170	Darlington and Teesdale Naturalists' Field Club.
25c. Corbridge	Durham	500	R. B. Cooke.
33c. Chester-le-Street	Durham	40	J. Baxter.
33d. Gateshead	Durham	550	G. H. Anderson.
33e. South Shields	Durham	10	W. Bennett.
33f. North Shields	Northumb.		J. B. Spence.
25d. Allendale	Northumb.	900	G. Stephenson.
38c. Lemmington, Alnwick	Northumb.	750	F. E. Lupton.
39a. Berwick-on-Tweed	Northumb.	50	J. B. Duncan.
J (1).			Observers: 20−6+3=17.
10b. Duns	Berwick	410	Senior Scholars, Duns School.
15a. Dunfermline	Fife	400	N. M. Johnson, B.Sc., L.C.P., F.R.S.G.S.
K (0).			Observers: 5−1+1=5.
27b. Kirkhill, Muir of Ord	Inverness	450	Mrs. V. M. Baird Ferguson.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1925.

The dates in *italics* are interpolated or estimated, and have not been taken into consideration when calculating the mean for Table IV. The figures immediately following the station names indicate the mean values used in drawing the isophenes, and in computing these, interpolated, as well as actual, values have been utilised.

Explanation of date Numbers, December 1 is —31; 31, —1.

1—31=Jan.	91—120=April.	182—212=July.	274—304=Oct.
32—59=Feb.	121—151=May.	213—243=Aug.	305—334=Nov.
60—90=Mar.	152—181=June.	244—273=Sept.	

Station.	Mean Value excluding Ivy and Scabious.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.	Devil's-Bit Scabious.	
A.																
Channel Isles: Guernsey.																
0a. Les Blanches	127	*60*	*68*	*80*	83	128	123	127	115	163	197	*204*	173	256	...	
0d. Les Hubits	125	53	*62*	*75*	74	119	124	127	*116*	164	198	*205*	*179*	260	...	
A (8)																
2c. Mawgan	128	51	69	73	83	128	131	131	138	163	193	*198*	175	293	229	
5a. Polperro	119	36	35	74	44	*101*	132	140	*144*	151	179	*207*	191	266	225	
5d. Bodmin	127	26	29	64	90	124	133	*144*	150	163	191	*210*	*195*	...	...	
6a. Duloe	120	27	*22*	46	89	116	135	145	148	155	177	*200*	177	271	218	
9a. Launceston	133	43	75	*89*	109	122	131	146	152	162	177	*206*	*188*	...	...	
6b. Tavistock	125	12	68	110	*105*	119	127	137	133	153	160	*193*	*178*	266	...	
6c. Lopwell	125	46	*45*	81	81	*106*	*128*	*129*	150	152	186	*211*	*187*	277	...	
9c. Clawton	136	38	*81*	*102*	106	112	143	144	162	165	183	*209*	188	...	...	
10b. Torquay	112	31	60	61	71	121	112	106	120	*140*	*160*	*190*	*172*	261	...	
10c. Brixham	129	*41*	64	*84*	92	103	127	*148*	*161*	174	167	*200*	185	278	...	
11c. Spreyton	137	*45*	71	102	102	109	131	148	167	168	188	*216*	*197*	...	...	
11d. Copplestone	120	8	60	*85*	88	112	133	139	145	161	*164*	172	*177*	...	...	
11e. Bridestowe	139	69	71	*99*	99	*116*	138	153	164	167	187	*215*	*193*	281	...	
12d. Appledore	116	*22*	*42*	*71*	64	102	142	121	*142*	149	166	*195*	*175*	272	23	
13a. Exmouth	127	25	46	99	88	105	124	132	150	158	188	*210*	200	265	22	
14b. Bishop's Tawton	125	47	47	81	82	106	126	138	145	159	167	*205*	194	276	21	
15a. Buckerell	130	48	79	79	97	114	134	149	159	164	164	*195*	177	277	...	
15b. Colyford	128	*48*	*64*	*81*	*90*	109	133	138	152	163	*166*	*203*	193	...	...	
* Combe Martin	119	41	36	*60*	71	106	126	130	147	158	163	*199*	187	255	20	
15c. Lyme Regis	128	36	46	90	88	119	136	*141*	*160*	*164*	*168*	*203*	*190*	262	...	
21d. Broadstone	126	*39*	*51*	92	*88*	117	135	140	161	156	*160*	201	171	244	...	
24d. West Melbury	131	45	60	105	60	111	*142*	145	*168*	172	*166*	*202*	191	...	...	
19f. Taunton	118	25	48	*71*	75	99	122	133	133	*155*	172	*201*	*182*	...	...	
19g. West Buckland	133	60	*77*	91	95	110	137	137	*152*	*159*	*175*	*205*	*192*	275	...	
22d. Bruton	128	33	57	74	98	112	134	142	148	158	183	*205*	195	262	...	
25b. Flax Bourton	119	18	35	86	65	110	131	132	152	155	162	190	*186*	...	19	
25c. Keynsham	125	43	49	90	83	114	130	*126*	152	158	163	*200*	188	251	22	
25f. Pensford	110	30	59	72	107	112	116	114	119	117	116	*185*	173	...	18	
27c. Portishead	114	16	42	63	79	108	124	128	141	154	155	187	174	246	18	
28b. Clevedon	124	28	*42*	*73*	73	*107*	128	138	145	160	194	*205*	194	276	...	
40a. Abergavenny	123	40	52	69	*96*	115	*121*	*140*	148	163	*165*	*195*	*168*	261	...	
29a. Bridgend	129	50	52	93	94	123	133	142	148	163	175	202	172	...	20	
30a. Mumbles	126	40	40	71	108	118	119	148	157	*176*	165	197	172	...	21	
32a/b. Tenby	127	36	51	99	89	118	125	126	130	177	187	*212*	179	...	...	

* Mean of the 3 stations 17a, b, d.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1925—*continued*.

Station.	Mean Value excluding Ivy and Scabious.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.	Devil's-Bit Scabious.
13a. St. Davids	129	*37*	30	*90*	99	*119*	122	142	*145*	174	194	190	205	266	206
34c. Philadelphia	127	48	61	69	82	119	127	142	145	163	190	*207*	177	283	...
39a. Llandovery	139	*65*	79	102	103	104	133	*146*	161	*173*	*200*	*215*	*183*	...	...
41a. Hafod	140	57	*77*	118	*110*	*123*	142	145	158	169	191	209	184	...	209
43b c. Aberystwyth	122	28	36	76	93	112	132	140	150	163	180	183	172	...	249
B (10)															
7a. Timoleague	120	35	50	42	75	*91*	121	139	137	*162*	*190*	*205*	*196*	...	...
11a. Monkstown	123	36	*38*	*66*	92	*95*	127	125	148	154	*193*	*208*	*200*	...	...
12b. Passage West	129	43	*45*	*68*	82	*92*	122	147	155	169	199	*212*	212	250	...
22b. Castle Lyons	124	54	35	67	*85*	*100*	121	128	143	166	191	208	192	253	221
30a. Cashel	141	73	*85*	100	100	*115	139	140	158	166	194	*201*	226	258	220
34b. Kilkenny	131	37	76	60	98	112	131	140	151	153	208	*210*	201	268	...
42a. Ballickmoyler	136	*62*	*75*	90	100	117	131	138	158	166	*191*	*209*	*198*	...	...
44a. Ferns	138	51	77	102	109	*125*	140	140	158	166	193	193	201	274	...
44d. Mountmellick	119	44	45	51	61	108	117	136	135	160	175	*211*	182	262	211
50a. Johnstown Bridge	136	*58*	*71*	*87*	96	*127*	139	144	153	166	*189*	*206*	*196*	276	...
C (5)															
4c. Salisbury	131	55	53	*80*	104	123	137	139	156	157	190	194	183	259	211
5c. Bratton	124	44	19	76	82	*120*	*135*	*138*	165	156	165	204	*180*	273	253
5b. Marlborough	121	32	53	76	89	122	*129*	124	146	160	168	181	177	272	...
1c. Boscombe	123	*30*	*35*	100	51	135	131	143	124	*161*	*172*	176	195	280	...
1b. Ringwood	122	31	*47*	100	82	108	134	136	*130*	161	170	193	177	271	...
1c. Lymington	123	44	47	94	92	118	128	137	139	152	173	168	186	274	224
3a. Shanklin	114	10	32	81	100	117	114	133	135	154	155	*168*	172	258	234
3b. Newport	116	24	41	71	76	79	132	138	140	145	177	186	*180*	261	257
3e. Southsea	130	50	63	81	101	113	129	135	156	160	*187*	197	193	271	217
4b. Sherfield English	120	21	62	62	88	110	130	135	144	152	172	183	184	290	...
5a. Havant	118	22	36	68	*85*	*115*	128	138	143	160	172	*175*	175	270	...
5d. Hayling Island	122	29	*58*	*75*	82	113	135	134	150	159	171	*175*	177	278	...
7a. Botley	126	17	67	80	105	118	134	138	145	160	161	*180*	201	265	227
7b. West Meon	129	51	*68*	73	104	126	135	142	156	160	160	*179*	188	260	...
7c. Hythe, Southampton	126	34	*69*	99	98	117	124	134	139	144	181	*186*	191	...	221
10b. Alton, Newton Valence	130	43	73	75	98	117	135	137	148	157	*185*	191	197	...	...
20a. Reading	122	34	41	*80*	*90*	105	131	137	141	160	*170*	*190*	189	...	243
5c. Chichester	121	10	73	81	91	107	127	139	143	158	165	185	172	275	...
10b. Hove	124	*20*	54	*70*	109	127	131	137	145	169	157	*185*	179	257	...
10d. Portslade	122	24	60	79	85	103	122	131	134	152	184	200	194	263	...
15d. Horsham	119	19	52	77	73	104	133	132	144	156	169	193	177	267	216
15a. Lewes	118	25	52	67	81	115	127	132	140	151	158	192	173	246	235
15b. Hellingly	122	30	59	60	98	100	132	136	139	152	180	*195*	183	253	...
15c. Ditchling	121	30	19	88	99	*105*	129	*135*	143	160	161	*195*	185	275	...
21a. Brede	122	28	*60*	60	89	112	136	137	142	162	*160*	*195*	*185*	...	...
16b. Farnham	118	27	64	61	76	107	124	127	140	150	158	*195*	182	256	...
16c. Rowledge	123	19	35	82	102	115	136	138	146	157	166	*195*	183	...	217
16a. Cranleigh	124	40	*40*	*70*	*96*	*110*	134	137	144	161	*165*	190	195	276	...
22a. Lingfield	120	8	35	69	98	105	135	142	149	160	161	186	190	282	215

* Observed at Clonmel, 13 miles S.E.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1925—*continued*.

Station.	Mean Value excluding Ivy and Scabious.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.	Devil's-Bit Scabious.
22b. Warlingham.	121	17	*30*	73	97	117	134	137	141	*155*	171	*190*	*192*	...	...
22c. Purley .	125	27	21	83	81	122	133	136	159	149	190	198	*195*	284	...
25a. Maidstone .	120	32	33	*70*	100	100	131	137	137	152	164	*195*	*195*	263	...
25b. Mereworth .	120	30	34	59	86	110	135	134	145	157	167	*190*	190	273	21
26a/b Bromley .	124	33	59	87	96	105	133	136	141	159	165	*190*	184	...	...
26d. Sydenham .	125	24	40	87	*99*	116	128	132	156	160	*165*	*190*	203	279	...
29b. Sandwich .	125	36	61	92	75	108	*126*	136	141	159	*170*	201	194	257	245
D (4)															
5b/c. Cheltenham	126	63	63	86	79	129	131	136	*139*	*158*	*147*	*189*	*188*	...	...
5d. Coaley .	118	22	51	65	71	117	134	136	139	158	147	189	188	266	223
6a. Dymock .	122	*40*	49	68	94	104	132	133	145	159	*160*	*190*	188	248	...
4a. Weobley .	118	1	39	75	*85*	108	127	138	*153*	159	172	*190*	173	...	...
4b. Staunton-on-Arrow	120	32	49	45	85	103	132	136	152	160	172	*190*	179	250	...
6c. Kimbolton .	128	44	45	82	110	103	132	135	156	156	176	197	196	242	226
6d. Colwall .	118	35	17	47	77	*103*	136	139	152	159	172	186	192	...	...
11b. Ludlow .	122	4	*20*	87	*90*	*103*	138	141	*155*	167	*185*	192	181	...	...
17a. Edgmond .	127	32	30	89	93	121	134	138	154	161	180	*195*	197	281	...
11a. Tenbury .	121	27	52	84	90	100	134	137	146	150	165	193	174	256	223
16b. Wolverley, Cookley	125	40	63	98	90	111	125	136	*146*	159	172	183	*175*	271	...
10c. Ashorne .	125	24	*60*	95	96	107	134	130	153	160	169	*195*	*180*	275	214
15c. Stratford-on-Avon	128	42	64	86	96	117	136	137	155	158	*170*	201	179	279	228
16d. Quinton .	127	34	48	98	106	111	138	143	149	166	170	179	185	258	229
16e. S. Birmingh'm	123	18	33	96	78	110	135	137	161	165	175	196	172	...	...
20a. Farnborough	126	11	47	74	94	112	134	137	144	188	178	198	193	...	...
21b. Erdington .	128	31	43	97	73	123	137	142	157	166	185	186	*190*	274	...
21d. Hampton-on-the-Hill	122	11	68	77	78	112	133	131	157	155	174	185	180	271	...
21f. Hall Green .	130	37	64	102	111	112	*133*	*137*	147	157	*175*	*190*	*195*	...	...
21g. King's Heath	135	53	74	101	104	129	140	139	*155*	165	170	195	*195*	...	...
26b. Sutton Coldfield.	133	35	69	102	*100*	121	140	141	159	161	180	190	198	...	214
14a/b. Oxford .	124	22	63	84	93	106	127	131	133	157	194	200	183	253	...
19a. Weston Turville .	128	*34*	*60*	98	*95*	*104*	136	129	149	161	179	200	186	...	...
19b. Granborough	127	32	*60*	79	95	104	*136*	132	156	161	*179*	*195*	*190*	262	...
24a. Bletchley .	131	47	61	*85*	108	*110*	136	134	157	158	190	190	193	280	...
20b. Marston, St. Lawrence	122	34	40	64	78	112	137	137	150	155	178	*185*	*190*	...	...
24b. Northampton	123	46	36	*64*	82	115	136	137	149	157	178	*185*	190	249	...
22a. Wolverhampton	128	*25*	45	*80*	*110*	130	140	139	*155*	*160*	*175*	192	181	274	...
30a. Mayfield .	122	24	33	74	90	116	137	138	154	158	174	*176*	195	...	...
34a. Kegworth .	129	27	55	*80*	94	123	134	133	160	161	177	199	201	265	...
35a. Somersal Herbert .	132	18	86	87	100	120	137	*137*	161	161	185	192	195	259	201
35b. Matlock .	127	20	32	91	110	118	136	139	145	161	187	193	195	255	203
37b. Balderton .	129	*30*	44	*91*	101	130	143	136	157	150	*180*	186	*195*	...	...
38a. Hodsock .	124	36	48	91	99	109	126	131	143	158	184	188	174	259	...
39b. Kirkheaton .	140	66	66	102	109	150	145	142	158	177	197	182	191	303	220

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1925—*continued*.

Station.	Mean Value excluding Ivy and Scabious.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.	Devil's-Bit Scabious.
39c. Thurlstone	143	72	76	*100*	*110*	*150*	145	143	161	168	*197*	196	*199*	...	...
39d. Sheffield	132	39	*50*	94	*100*	*120*	140	141	154	165	197	186	198	...	...
41d. Crosshills	129	32	38	100	101	132	140	141	159	162	172	178	196	268	209
45a. Middlestown	136	25	75	75	115	*140*	157	136	169	167	191	189	*195*	290	...
45b. Altofts	133	35	46	*80*	*110*	138	142	141	160	168	189	*188*	194	...	...
E (3)															
1d. Whetstone	123	29	35	*88*	79	124	127	136	143	163	168	*190*	194	273	...
2a. Berkhamsted	130	17	42	101	99	113	136	143	148	161	194	204	201	...	...
2b. Tring	119	15	36	77	97	123	124	125	159	152	177	182	166	...	...
4c. Harpenden	125	36	45	96	95	113	138	136	143	153	165	194	191	255	...
* Hitchin	122	25	44	101	81	114	132	137	139	150	171	194	175	256	...
4k. Pirton, Hitchin	131	41	71	89	88	116	136	134	154	147	178	205	211	249	226
7b. Sawbridgw'th	124	25	31	92	101	108	134	132	145	156	172	*195*	194	268	...
7f. Buntingford	123	1	60	*93*	76	129	135	131	138	153	181	*200*	181	...	221
8a,b Letchworth	121	22	16	96	93	126	136	134	144	154	168	189	175	270	...
9a. Turvey	126	32	45	80	88	119	134	133	153	155	188	*190*	199	...	226
8e. Kempston	121	18	39	87	73	122	124	127	*150*	155	179	*185*	196	...	...
10b. Halstead	121	23	49	76	*100*	*106*	134	138	146	154	*170*	173	186	266	...
10f. Gt. Totham	120	43	49	76	109	*110*	*130*	130	134	135	*165*	*175*	*185*	255	...
13a. Lexden	121	40	50	93	83	110	130	129	142	148	159	179	*185*	265	...
14a. Ballingdon	123	22	37	74	100	103	134	131	143	155	181	195	195	277	...
17d. Bramford, Ipswich	125	46	58	94	*100*	109	125	134	139	153	178	*180*	182	...	...
23a. Bungay	121	25	40	60	91	*110*	130	122	*145*	163	200	179	186	270	229
22b. Langford, Watton	131	39	*65*	*75*	102	126	133	137	152	160	169	202	203	264	220
24a. Norwich	128	32	*73*	74	101	110	134	135	144	161	*179*	*195*	*200*	258	...
24b. Postwick	130	28	74	*80*	*110*	118	138	136	142	154	197	188	200	274	...
25a. Hunstanton	131	32	61	*75*	116	127	133	136	154	158	193	*195*	189	248	...
28b. Stalham	133	29	50	110	102	115	135	138	150	163	200	200	200	256	...
F (7)															
9a. Beaumaris	128	54	34	88	94	118	119	140	156	167	188	195	182	260	222
10a. Wrexham	116	†38	22	62	*78*	100	131	131	136	154	180	*186*	178	...	217
11d. Trefnant	124	23	33	70	101	124	148	*136*	150	158	*185*	*192*	*172*	...	...
11e. Dolben, St. Asaph	118	33	52	78	*69*	100	109	*115*	155	*143*	187	195	*175*	...	...
13c. Hr. Tranmere	123	38	24	*81*	91	115	*121*	126	159	156	188	*186*	*196*	268	...
13d. Shotwick	132	55	66	88	*100*	105	135	143	*148*	155	196	201	197	255	...
14a. Barnton	129	38	35	87	96	115	122	148	151	170	187	185	209	279	208
14b. Altrincham	130	59	67	93	95	106	136	134	154	163	181	192	181	...	...
16a. Prestbury	137	41	51	89	122	140	140	145	159	166	198	199	200	...	227
16b. Bramhall	131	*40*	41	93	86	126	*128*	153	147	160	*180*	208	208	...	...
18a. Blackpool	129	*45*	46	*86*	*84*	118	142	139	158	167	*173*	194	199	283	...
19a. Stockport	128	57	45	83	*87*	124	112	123	153	176	171	193	211	...	214
21a. Leyland	135	41	64	88	*105*	*131*	135	138	164	162	*188*	204	204	295	228
21b. Ashton-on-Ribble	128	*29*	44	98	101	120	136	138	150	155	*180*	‡193	*197*	...	...
22a. Urswick	133	37	57	81	99	124	141	142	162	163	191	191	210	267	224
25b. Ambleside	125	24	59	78	112	115	143	132	140	161	182	171	185	302	...
25b. Johnby Hall	153	96	113	129	121	147	159	155	155	160	*197*	199	*207*	...	...
28c. Mungrisdale	136	63	74	91	99	130	150	144	*147*	*160*	*189*	*185*	*196*	...	...
31a. Kelsick	144	*61*	65	127	125	141	*158*	143	161	164	194	191	*203*	...	...

* Mean of the 3 stations 4g, h, i. † Observed at Llangollen, 11 miles S.W. ‡ Observed at Grasmere.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1925—*continued*.

Station.	Mean Value excluding Ivy and Scabious.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.	Devil's-Bit Scabious.
G (9)															
18a. Longford	127	46	*39*	84	88	*96*	132	145	157	168	*185*	191	*190*	...	...
32b. Levally	136	69	41	70	117	*113	145	145	161	171	194	*199*	208	283	220
41c. Scarva	137	48	40	*80*	126	*111*	152	147	*167*	162	*201*	*199*	*205*	276	...
35c. Warrenpoint.	122	20	35	76	79	*95*	134	142	158	164	193	*184*	188	277	...
35d. Rostrevor	133	*43*	63	83	109	*116*	138	141	161	*166*	*194*	*185*	*198*	265	...
50a. Hillsborough	143	*59*	74	*104*	127	130	140	149	162	170	*197*	*189*	211	279	...
47a. Sixtowns	135	38	67	88	101	*117*	144	151	164	168	196	*187*	*205*	272	203
48a. Altnafoyle	138	*42*	61	90	111	*117*	155	139	*163*	*169*	208	*188*	*208*	...	216
51a. Magherafelt	135	44	62	84	99	*112*	145	149	153	162	192	*205*	*217*	...	...
50c. Belfast	126	*36*	43	57	76	*90*	130	132	163	179	*208*	*195*	*199*	...	...
50d. Muckamore	130	*35*	35	78	111	*96*	137	149	161	167	204	*188*	195	300	18
50f. Woodburn, Belfast	131	*57*	40	*82*	110	109	148	144	*159*	152	*198*	*186*	*189*	283	221
54a. Hazelbank	129	52	43	81	82	*95*	127	140	169	170	*202*	191	193	272	22
54b. Larne	132	*52*	*57*	86	96	*100*	126	142	157	163	201	191	214	265	...
55a. Ballymoney	134	*62*	51	93	94	*104*	139	135	160	169	†201	†194	*210*	...	...
H (6)															
1a. Kirkmaiden	128	41	46	96	86	118	125	135	153	15)	196	191	186	275	22
27a. Larkhall	129	67	62	82	*98*	*110*	*129*	130	138	164	*190*	195	195	...	22
33a. Ledaig, Oban	138	19	97	106	97	*124*	134	146	*155*	*172*	*203*	*203*	*201*	...	...
I (2)															
5b. Kirton, Boston	125	*27*	48	84	101	118	135	141	151	151	177	*180*	*190*	297	...
10a. West Keal	135	36	*54*	*97*	108	129	133	146	*165*	167	*194*	*193*	*202*	...	...
11d. Cleethorpes	126	38	45	99	80	118	131	134	155	152	187	181	189	281	22
20a. Louth	138	39	*58*	*108*	*100*	130	137	137	165	165	*198*	200	214	...	21
12a. Howdenshire	130	15	52	98	100	*127*	137	140	151	163	190	*194*	194	266	...
13a. Osgodby, Selby	134	*33*	59	*106*	*111*	127	140	138	155	168	*189*	*196*	191	...	...
21a. Hull	127	37	50	100	109	113	126	*125*	131	156	184	194	198	288	...
23a. Thirsk	127	21	61	09	102	108	140	140	153	163	176	176	*187*	...	...
24b. Darlington	128	38	39	88	94	115	135	134	156	163	193	186	*200*	276	21
33a. Lanchester	132	36	32	102	*101*	112	148	147	162	164	193	188	*197*	...	...
33b. Chopwell	130	52	32	88	89	102	150	146	156	164	196	192	196	300	20
25a/c. Corbridge	135	43	45	104	108	128	143	146	159	*164*	*194*	*190*	*196*	...	...
36a. S'ton Delaval	129	36	33	92	92	*102*	*141*	141	*156*	175	189	200	185	...	...
38c. Lemmington	137	53	59	102	111	114	145	143	168	163	190	192	210	207	22
39a. Berwick	135	*41*	43	*86*	115	127	143	145	165	167	*190*	*196*	*198*	...	21
J (1)															
6b. Jedburgh	139	44	*53*	100	*113*	120	153	147	170	165	207	199	202	287	21
4a. Selkirk	141	*48*	53	97	115	144	147	151	164	171	193	193	214	...	...
6a. Galashiels	134	49	56	94	112	100	*144*	*145*	*161*	160	*194*	191	*202*	...	...
2a. Broughton	147	62	73	106	137	*145*	153	153	166	166	190	191	*221*	...	...
10a. W. Foulden	139	55	*61*	93	*121*	121	141	140	159	168	191	191	226	...	22
13a. Stirling	146	73	*59*	99	*118*	*126*	152	152	173	*175*	*198*	*199*	*231*	...	...
15a. Dunfermline	141	*51*	73	110	105	*109*	152	155	*165*	164	*193*	*194*	*226*	...	...
21a. Dundee	140	51	53	103	*113*	*115*	143	150	165	166	202	*192*	*225*	...	20
35b. Alford	147	*54*	66	112	*112*	*115*	*150*	153	169	174	198	204	234	...	21
36a. Cabrach	155	77	97	114	120	126	149	161	177	195	200	209	*229*	...	21
39a. Dunlugas	147	*56*	89	95	126	157	145	153	159	176	201	191	213	...	21
39b. Forglen	145	*55*	76	108	117	*130*	151	151	162	*174*	208	202	*210*	285	21
K (0).															
27b. Kirkhill	137	‡43	89	95	129	137	109	110	161	162	*203*	195	*209*	...	...
Total records used		221	220	209	231	204	231	254	205	231	165	117	151	141	8

* Observed at Enniskillen. † Observed at Port Gallintræ, 12 miles distant. ‡ Observed at Davict

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TABLE IIIa.—Additional Flower Records.

District.	Snowdrop (*G. nivalis*).	Winter Aconite (*E. hiemalis*).	Yellow Crocus (*C. aureus*).	Celandine (*R. ficaria*).	Mean.
Channel Isles	...	...	...	(7)	...
A (8) England S.W.	13	14	26	19	18
B (10) Ireland S.	7	6	24	28	16
C (5) England S.E.	18	13	26	28	21
D (4) Midlands	15	17	35	49	29
E (3) England E.	13	14	28	41	24
F (7) England N.W.	17	19	31	40	27
G (9) Ireland N.	14	14	29	25	21
H (6) Scotland W.	11	[13]	34	(57)	29
I (2) England N.E.	21	15	42	60	35
J (1) Scotland E.	25	26	62	74	47
K (0) Scotland N.	22	(7)	60	[94]	46
Records Used	248	142	217	248	(855)
Mean of All	16.0	14.4	36.1	46.8	28.3
Month and Day	J.16	J.14	F.5	F.16	J.28
Average, 12 yrs., 1913-24	19.3	19.5	34.1	48.1	30.2
Month and Day	J.19	J.19	F.3	F.17	J.30

( ) Signifies mean of two observations only, [ ] of one.

(*Continued from page* 286.)

SUMMARY OF OBSERVERS' NOTES.

Plants. The extremely mild December gave numerous records of late flower survivals, with some early dates for the coltsfoot and celandine in various districts. C22c, 25 wild and 33 garden flowers in Dec., 1st coltsfoot on 26th. G54a, average date from 200 flowers two to three days before 1924; 52 wild last week Oct. Many report profuse and early primrose bloom; unusual lateness of ash; rush of leafing and blooming from sudden mid-May heat after preceding chilly weather; E4g "a fairy world of blossom"; A29a, buds long dormant burst out together, all late up to rose; E4c, may and rose flower together, June 3rd; meadows lovely. Then June drought and heat hurtful; recovery later and fine garden results; roses best in autumn; wild flowers and gardens specially fine in N, even in Oct. and early Nov.; C18c, 28 wild, Nov. 13.

Weather Notes, in addition to above; rarely a winter so free of frost and snow; rains serious for garden and farm; seed beds spoilt; cold spring; June drought in parts a record; intense Nov. frosts and into December affect more 1926; I19a, 6 weeks to end of year; longest since 1880/1 and destructive to crops and birds.

Profuse Flowering evokes rather limited comment. Of trees, apple, pear, plum, laburnum, elder, but their fruit often failed from early May cold and June drought. Besides primrose, foxglove was most conspicuous, A9c, "thousands"; and the Lakes, F28, with wild roses, especially the deep pink *R. mollis*. Later on, in SW as A22c, summer annuals, especially sweet peas and asters; ivy, too, in the S, but its fruit largely killed in Nov.

(*Continued on page* 306.)

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TABLE IV.—Mean Dates (Day of Year) for the Flowering of Fourteen Plants in 1925 and Difference from the Average of the 35 Years 1891-1925.

Plants.	Channel Isles 1925.	A (8) England, S.W. 1925.	A (8) Average 35 years.	A (8) Difference from 35-year Average.	A (8) Average 30 years.	B (10) Ireland, S. 1925.	B (10) Average 35 years.	B (10) Difference from 35-year Average.	B (10) Average 30 years.	C (5) England, S.E. 1925.	C (5) Average 35 years.	C (5) Difference from 35-year Average.	C (5) Average 30 years.	D (4) England, Mid. 1925.	D (4) Average 35 years.	D (4) Difference from 35-year Average.	D (4) Average 30 years.	E (3) England, E. 1925.	E (3) Average 35 years.	E (3) Difference from 35-year Average.	E (3) Average 30 years.	F (7) England, N.W. 1924.	F (7) Average 35 years.	F (7) Difference from 35-year Average.	F (7) Average 30 years.
1. *Corylus avellana*	[53]	37	38	− 1	39	46	33	+13	32	30	32	− 2	33	34	41	− 7	42	31	35	− 4	36	45	43	+ 2	43
2. *Tussilago farfara*	...	53	55	− 2	55	57	58	− 1	59	46	58	− 12	60	54	63	− 9	64	44	61	− 17	62	52	62	− 10	64
3. *Anemone nemorosa*	...	83	84	− 1	85	76	77	− 1	79	79	82	− 3	82	84	89	− 5	90	86	88	− 2	88	90	90	± 0	91
4. *Prunus spinosa*	121	86	89	− 3	91	92	82	+10	83	89	94	− 5	94	93	99	− 6	100	92	96	− 4	97	103	102	+ 1	102
5. *Sisymbrium alliaria*	(123)	113	107	+ 6	107	113	112	+ 1	113	113	110	+ 3	110	117	113	+ 4	113	116	111	+ 5	112	121	122	− 1	122
6. *Æsculus hippocastanum*	(123)	130	122	+ 8	122	129	123	+ 6	123	131	126	+ 5	126	135	130	+ 5	130	132	126	+ 6	126	135	132	+ 3	132
7. *Cratægus oxyacantha*	(127)	137	130	+ 7	130	139	131	+ 8	131	135	130	+ 5	131	137	133	+ 4	134	133	131	+ 2	131	140	138	+ 2	138
8. *Chrysanthemum leucanthemum*	[115]	148	145	+ 3	145	150	144	+ 6	144	145	141	+ 4	141	153	149	+ 4	148	145	145	± 0	145	154	154	± 0	153
9. *Rosa canina*	(163)	160	155	+ 5	155	163	158	+ 5	158	156	155	+ 1	155	161	159	+ 2	158	154	155	− 1	156	162	162	± 0	162
10. *Centaurea nigra*	(197)	175	172	+ 3	172	193	184	+ 9	183	170	171	− 1	171	179	177	+ 2	177	179	177	+ 2	177	189	189	± 0	189
11. *Campanula rotundifolia*	...	192	193	− 1	193	(201)	185	(+16)	184	190	186	+ 4	185	190	191	− 1	190	191	189	+ 2	189	194	188	+ 6	187
12. *Convolvulus sepium*	(176)	183	186	− 3	187	202	192	+10	192	186	187	− 1	187	188	191	− 3	191	190	190	± 0	191	198	196	+ 2	195
13. *Hedera helix*	(258)	267	264	+ 3	263	266	263	+ 3	262	269	269	± 0	269	266	268	− 2	268	264	266	− 2	265	275	277	− 2	277
14. *Scabiosa succisa*	...	212	...	...	...	210	...	...	...	227	...	...	...	217	...	...	...	224	...	...	...	220	...	...	...
Mean of Plants 1-13	...	136	134	+ 2	134	141	134	+ 7	134	134	135	+ 1	134	138	139	− 1	139	135	136	− 1	137	143	143	± 0	143
Mean of Plants 1-14	...	141	...	...	...	145	...	...	...	140	...	...	...	143	...	...	...	141	...	...	...	148	...	...	...

Plants.	G (9) Ireland, N. 1925.	G (9) Average 35 years.	G (9) Difference from 35-year Average.	G (9) Average 30 years.	H (6) Scotland, W. 1925.	H (6) Average 35 years.	H (6) Difference from 35-year Average.	H (6) Average 30 years.	I (2) England, N.E. 1925.	I (2) Average 35 years.	I (2) Difference from 35-year Average.	I (2) Average 30 years.	J (1) Scotland, E. 1925.	J (1) Average 35 years.	J (1) Difference from 35-year Average.	J (1) Average 30 years.	K (0) Scotland, N. 1925.	K (0) Average 35 years.	K (0) Difference from 35-year Average.	K (0) Average 30 years.	England and Wales.* 1925.	England and Wales.* Average 35 years.	England and Wales.* Difference from 35-year Average.	England and Wales.* Average 30 years.	British Isles. † 1925.	British Isles. † Average 35 years.	British Isles. † Difference from 35-year Average.	British Isles. † Average 30 years.
1. Hazel	45	48	− 3	49	42	49	− 7	47	39	46	− 7	48	58	55	+ 3	55	[43]	50	[− 7]	48	36	39	− 3	40	41	44	− 3	44
2. Coltsfoot	50	67	−17	69	68	67	+ 1	69	52	64	−12	66	77	73	+ 4	73	[89]	76	[+13]	74	50	60	−10	62	58	64	− 6	65
3. Wood Anemone	81	88	− 7	88	95	97	− 2	97	98	93	+ 5	93	103	104	− 1	104	(105)	107	(− 2)	107	87	88	− 1	88	89	91	− 2	92
4. Blackthorn	105	100	+ 5	101	101	112	−11	114	103	107	− 4	108	119	116	+ 3	116	[129]	115	[+14]	115	94	98	− 4	98	101	101	± 0	102
5. Garlic Hedge-Mustard	117	112	+ 5	110	(119)	127	(− 8)	127	120	121	− 1	121	128	128	± 0	128	[137]	128	[+ 9]	128	117	114	+ 3	114	119	119	± 0	120
6. Horse-Chestnut	139	131	+ 8	131	(129)	142	(−13)	142	139	138	+ 1	139	149	145	+ 4	145	(129)	142	(−13)	143	134	129	+ 5	129	134	133	+ 1	133
7. Hawthorn	143	138	+ 5	138	141	145	− 4	145	142	139	+ 3	140	151	148	+ 3	148	(129)	152	(− 23)	152	137	133	+ 4	134	139	139	± 0	139
8. White Ox-Eye	162	155	+ 7	155	152	160	− 8	160	157	157	± 0	158	166	164	+ 2	163	[161]	167	[− 6]	166	150	148	+ 2	148	154	154	± 0	154
9. Dog Rose	167	165	+ 2	165	160	166	− 6	166	164	167	− 3	168	171	169	+ 2	169	177	169	+ 8	167	159	159	± 0	159	163	163	± 0	163
10. Black Knapweed	199	198	+ 1	198	[196]	199	[− 3]	199	187	192	− 5	193	200	198	+ 2	197	[203]	204	[− 1]	203	180	180	± 0	180	188	190	− 2	190
11. Harebell	192	196	− 4	194	(193)	194	(− 1)	193	190	191	− 1	191	197	195	+ 2	195	[195]	197	[− 2]	197	191	189	+ 2	189	193	192	+ 1	192
12. Greater Bindweed	201	203	− 2	204	(191)	198	(− 7)	198	197	198	− 1	199	218	207	+11	206	[269]	202	[+ 7]	200	190	191	− 1	191	197	198	− 1	198
13. Ivy	277	277	± 0	276	[275]	277	[− 2]	277	286	280	+ 6	280	(286)	290	(− 4)	289	[285]	291	[− 6]	290	271	270	+ 1	270	274	276	− 2	276
14. Devil's-Bit Scabious	211	...	...	...	(227)	...	...	...	217	...	...	...	215	...	...	...	[226]	...	...	...	219	...	...	...	219	...	...	...
Mean of Plants 1-13	144	144	± 0	144	143	149	− 6	149	144	146	− 2	146	156	153	+ 3	153	153	154	− 1	153	138	138	± 0	139	142½	143½	− 1	143½
Mean of Plants 1-14	149	...	...	...	149	...	...	...	149	...	...	...	160	...	...	...	158	...	...	...	144	...	...	...	148	...	...	...

* Average of Districts A, C, D, E, F, I. + Signifies that the date of flowering is later; − that it is earlier. † The mean of the 13 plants for the British Isles

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TABLE V.—Mean Dates of Flowering, with their Variations from the 35 Years' Average (1891-1925), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made. Also, Total Number of Stations in all Eleven Districts.

Years.	No. of Stations.	A (8), Eng. S.W.		C (5), Eng. S.E.		D (4), Eng. Mid.		E (3), Eng. E.		F (7), Eng. N.W.		Mean Variation from Average for the 5 Districts.
		Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	
			Days.		Days.		Days.		Days.		Days.	Days.
1891	105	144	+10	144	+ 9	150	+11	147	+11	150	+ 7	+ 9.6
1892†	107	139	+ 5	138	+ 3	144	+ 5	143	+ 7	147	+ 4	+ 4.8
1893	117	118	−16	122	−13	125	−14	123	−13	128	−15	−14.2
1894	113	126	− 8	130	− 5	135	− 4	127	− 9	137	− 6	− 6.4
1895	118	139	+ 5	138	+ 3	141	+ 2	138	+ 2	144	+ 1	+ 2.6
1896†	115	125	− 9	128	− 7	132	− 7	130	− 6	134	− 9	− 7.6
1897	110	130	− 4	132	− 3	136	− 3	132	− 4	142	− 1	− 3.0
1898	127	133	− 1	135	0	138	− 1	136	0	141	− 2	− 0.8
1899	116	136	+ 2	136	+ 1	141	+ 2	138	+ 2	145	+ 2	+ 1.8
1900	119	142	+ 8	141	+ 6	144	+ 5	143	+ 7	152	+ 9	+ 7.0
1901	125	138	+ 4	139	+ 4	141	+ 2	139	+ 3	144	+ 1	+ 2.8
1902	124	139	+ 5	140	+ 5	145	+ 6	142	+ 6	152	+ 9	+ 6.2
1903	118	134	0	134	− 1	137	− 2	134	− 2	145	+ 2	− 0.6
1904†	115	139	+ 5	139	+ 4	142	+ 3	140	+ 4	149	+ 6	+ 4.4
1905	117	133	− 1	135	0	138	− 1	136	0	144	+ 1	− 0.2
1906	108	135	+ 1	134	− 1	138	− 1	137	+ 1	143	0	0
1907	109	142	+ 8	139	+ 4	143	+ 4	142	+ 6	149	+ 6	+ 5.6
1908†	116	139	+ 5	138	+ 3	142	+ 3	142	+ 6	148	+ 5	+ 4.4
1909	109	140	+ 6	140	+ 5	144	+ 5	142	+ 6	150	+ 7	+ 5.8
1910	107	136	+ 2	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.6
1911	104	135	+ 1	133	− 2	137	− 2	134	− 2	133	−10	− 3.0
1912†	107	127	− 7	128	− 7	132	− 7	130	− 6	137	− 6	− 6.6
1913	125	125	− 9	126	− 9	134	− 5	130	− 6	142	− 1	− 6.0
1914	132	126	− 8	128	− 7	133	− 6	129	− 7	135	− 8	− 7.2
1915	127	133	− 1	134	− 1	139	0	137	+ 1	142	− 1	− 0.4
1916†	117	132	− 2	132	− 3	141	+ 2	140	+ 4	142	− 1	0
1917	114	141	+ 8	141	+ 6	149	+10	145	+ 9	148	+ 5	+ 7.6
1918	110	131	− 3	131	− 4	134	− 5	134	− 2	135	− 8	− 4.4
1919	103	134	0	134	− 1	141	+ 2	140	+ 4	141	− 2	+ 0.6
1920†	212	126	− 8	123	−12	131	− 8	129	− 7	137	− 6	− 8.2
1921	205	125	− 9	120	−15	127	−12	125	−11	133	−10	−11.4
1922	239	137	+ 3	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.8
1923	357	129	− 5	130	− 5	136	− 3	131	− 5	145	+ 2	− 3.2
1924†	365	139	+ 5	138	+ 3	144	+ 5	141	+ 5	149	+ 6	+ 4.8
1925	362	136	+ 2	134	− 1	138	− 1	135	− 1	143	0	− 0.2
Average 1891-1925	...	134	...	135	...	139	...	136	...	143	...	[137.4]
		My. 14		My. 15		My. 19		My. 16		My. 23		[My17]

† Leap years.

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TABLE IV.—Mean Dates (Day of Year) for the Flowering of Fourteen Plants in 1925 and Difference from the Average of the 35 Years 1891-1925.

Plants.	Channel Isles 1925.	A (8) England, S.W. 1925.	A (8) Average 35 years.	A (8) Difference from 35-year Average.	A (8) Average 30 years.	B (10) Ireland, S. 1925.	B (10) Average 35 years.	B (10) Difference from 35-year Average.	B (10) Average 30 years.	C (5) England, S.E. 1925.	C (5) Average 35 years.	C (5) Difference from 35-year Average.	C (5) Average 30 years.	D (4) England, Mid. 1925.	D (4) Average 35 years.	D (4) Difference from 35-year Average.	D (4) Average 30 years.	E (3) England, E. 1925.	E (3) Average 35 years.	E (3) Difference from 35-year Average.	E (3) Average 30 years.	F (7) England, N.W. 1924.	F (7) Average 35 years.	F (7) Difference from 35-year Average.	F (7) Average 30 years.
1. *Corylus avellana*	[53]	37	38	− 1	39	46	33	+13	32	30	32	− 2	33	34	41	− 7	42	31	35	− 4	36	45	43	+ 2	43
2. *Tussilago farfara*	...	53	55	− 2	55	57	58	− 1	59	46	58	− 12	60	54	63	− 9	64	44	61	− 17	62	52	62	− 10	64
3. *Anemone nemorosa*	...	83	84	− 1	85	76	77	− 1	79	79	82	− 3	82	84	89	− 5	90	86	88	− 2	88	90	90	± 0	91
4. *Prunus spinosa*	121	86	89	− 3	91	92	82	+10	83	89	94	− 5	94	93	99	− 6	100	92	96	− 4	97	103	102	+ 1	102
5. *Sisymbrium alliaria*	(123)	113	107	+ 6	107	113	112	+ 1	113	113	110	+ 3	110	117	113	+ 4	113	116	111	+ 5	112	121	122	− 1	122
6. *Æsculus hippocastanum*	(123)	130	122	+ 8	122	129	123	+ 6	123	131	126	+ 5	126	135	130	+ 5	130	132	126	+ 6	126	135	132	+ 3	132
7. *Cratægus oxyacantha*	(127)	137	130	+ 7	130	139	131	+ 8	131	135	130	+ 5	131	137	133	+ 4	134	133	131	+ 2	131	140	138	+ 2	138
8. *Chrysanthemum leucanthemum*	[115]	148	145	+ 3	145	150	144	+ 6	144	145	141	+ 4	141	153	149	+ 4	148	145	145	± 0	145	154	154	± 0	153
9. *Rosa canina*	(163)	160	155	+ 5	155	163	158	+ 5	158	156	155	+ 1	155	161	159	+ 2	158	154	155	− 1	156	162	162	± 0	162
10. *Centaurea nigra*	(197)	175	172	+ 3	172	193	184	+ 9	183	170	171	− 1	171	179	177	+ 2	177	179	177	+ 2	177	189	189	± 0	189
11. *Campanula rotundifolia*	...	192	193	− 1	193	(201)	185	(+16)	184	190	186	+ 4	185	190	191	− 1	190	191	189	+ 2	189	194	188	+ 6	187
12. *Convolvulus sepium*	(176)	183	186	− 3	187	202	192	+10	192	186	187	− 1	187	188	191	− 3	191	190	190	± 0	191	198	196	+ 2	195
13. *Hedera helix*	(258)	267	264	+ 3	263	266	263	+ 3	262	269	269	± 0	269	266	268	− 2	268	264	266	− 2	265	275	277	− 2	277
14. *Scabiosa succisa*	...	212	...	...	...	210	...	...	...	227	...	...	...	217	...	...	...	224	...	...	...	220	...	...	...
Mean of Plants 1-13	...	136	134	+ 2	134	141	134	+ 7	134	134	135	+ 1	134	138	139	− 1	139	135	136	− 1	137	143	143	± 0	143
Mean of Plants 1-14	...	141	...	...	...	145	...	...	...	140	...	...	...	143	...	...	...	141	...	...	...	148	...	...	...

Plants.	G (9) Ireland, N. 1925.	G (9) Average 35 years.	G (9) Difference from 35-year Average.	G (9) Average 30 years.	H (6) Scotland, W. 1925.	H (6) Average 35 years.	H (6) Difference from 35-year Average.	H (6) Average 30 years.	I (2) England, N.E. 1925.	I (2) Average 35 years.	I (2) Difference from 35-year Average.	I (2) Average 30 years.	J (1) Scotland, E. 1925.	J (1) Average 35 years.	J (1) Difference from 35-year Average.	J (1) Average 30 years.	K (0) Scotland, N. 1925.	K (0) Average 35 years.	K (0) Difference from 35-year Average.	K (0) Average 30 years.	England and Wales.* 1925.	England and Wales.* Average 35 years.	England and Wales.* Difference from 35-year Average.	England and Wales.* Average 30 years.	British Isles. † 1925.	British Isles. † Average 35 years.	British Isles. † Difference from 35-year Average.	British Isles. † Average 30 years.
1. Hazel	45	48	− 3	49	42	49	− 7	47	39	46	− 7	48	58	55	+ 3	55	[43]	50	[− 7]	48	36	39	− 3	40	41	44	− 3	44
2. Coltsfoot	50	67	−17	69	68	67	+ 1	69	52	64	−12	66	77	73	+ 4	73	[89]	76	[+13]	74	50	60	−10	62	58	64	− 6	65
3. Wood Anemone	81	88	− 7	88	95	97	− 2	97	98	93	+ 5	93	103	104	− 1	104	(105)	107	(− 2)	107	87	88	− 1	88	89	91	− 2	92
4. Blackthorn	105	100	+ 5	101	101	112	−11	114	103	107	− 4	108	119	116	+ 3	116	[129]	115	[+14]	115	94	98	− 4	98	101	101	± 0	102
5. Garlic Hedge-Mustard	117	112	+ 5	110	(119)	127	(− 8)	127	120	121	− 1	121	128	128	± 0	128	[137]	128	[+ 9]	128	117	114	+ 3	114	119	119	± 0	120
6. Horse-Chestnut	139	131	+ 8	131	(129)	142	(−13)	142	139	138	+ 1	139	149	145	+ 4	145	(129)	142	(−13)	143	134	129	+ 5	129	134	133	+ 1	133
7. Hawthorn	143	138	+ 5	138	141	145	− 4	145	142	139	+ 3	140	151	148	+ 3	148	(129)	152	(− 23)	152	137	133	+ 4	134	139	139	± 0	139
8. White Ox-Eye	162	155	+ 7	155	152	160	− 8	160	157	157	± 0	158	166	164	+ 2	163	[161]	167	[− 6]	166	150	148	+ 2	148	154	154	± 0	154
9. Dog Rose	167	165	+ 2	165	160	166	− 6	166	164	167	− 3	168	171	169	+ 2	169	177	169	+ 8	167	159	159	± 0	159	163	163	± 0	163
10. Black Knapweed	199	198	+ 1	198	[196]	199	[− 3]	199	187	192	− 5	193	200	198	+ 2	197	[203]	204	[− 1]	203	180	180	± 0	180	188	190	− 2	190
11. Harebell	192	196	− 4	194	(193)	194	(− 1)	193	190	191	− 1	191	197	195	+ 2	195	[195]	197	[− 2]	197	191	189	+ 2	189	193	192	+ 1	192
12. Greater Bindweed	201	203	− 2	204	(191)	198	(− 7)	198	197	198	− 1	199	218	207	+11	206	[269]	202	[+ 7]	200	190	191	− 1	191	197	198	− 1	198
13. Ivy	277	277	± 0	276	[275]	277	[− 2]	277	286	280	+ 6	280	(286)	290	(− 4)	289	[285]	291	[− 6]	290	271	270	+ 1	270	274	276	− 2	276
14. Devil's-Bit Scabious	211	...	...	...	(227)	...	...	...	217	...	...	...	215	...	...	...	[226]	...	...	...	219	...	...	...	219	...	...	...
Mean of Plants 1-13	144	144	± 0	144	143	149	− 6	149	144	146	− 2	146	156	153	+ 3	153	153	154	− 1	153	138	138	± 0	139	142½	143½	− 1	143½
Mean of Plants 1-14	140	...	...	...	149	...	...	...	149	...	...	...	160	...	...	...	158	...	...	...	144	...	...	...	148	...	...	...

* Average of Districts A, C, D, E, F, I. + Signifies that the date of flowering is late: − that it is early. † The mean of the 18 plants for the British Isles

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TABLE V.—Mean Dates of Flowering, with their Variations from the 35 Years' Average (1891-1925), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made. Also, Total Number of Stations in all Eleven Districts.

Years.	No. of Stations.	A (8), Eng. S.W.		C (5), Eng. S.E.		D (4), Eng. Mid.		E (3), Eng. E.		F (7), Eng. N.W.		Mean Variation from Average for the 5 Districts.
		Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	
			Days.		Days.		Days.		Days.		Days.	Days.
1901	105	144	+10	144	+ 9	150	+11	147	+11	150	+ 7	+ 9.6
1902†	107	139	+ 5	138	+ 3	144	+ 5	143	+ 7	147	+ 4	+ 4.8
1903	117	118	−16	122	−13	125	−14	123	−13	128	−15	−14.2
1904	113	126	− 8	130	− 5	135	− 4	127	− 9	137	− 6	− 6.4
1905	118	130	+ 5	138	+ 3	141	+ 2	138	+ 2	144	+ 1	+ 2.6
1906†	115	125	− 9	128	− 7	132	− 7	130	− 6	134	− 9	− 7.6
1907	110	130	− 4	132	− 3	136	− 3	132	− 4	142	− 1	− 3.0
1908	127	133	− 1	135	0	138	− 1	136	0	141	− 2	− 0.8
1909	116	136	+ 2	136	+ 1	141	+ 2	138	+ 2	145	+ 2	+ 1.8
1910	119	142	+ 8	141	+ 6	144	+ 5	143	+ 7	152	+ 9	+ 7.0
1911	125	138	+ 4	139	+ 4	141	+ 2	139	+ 3	144	+ 1	+ 2.8
1912	124	139	+ 5	140	+ 5	143	+ 6	142	+ 6	152	+ 9	+ 6.2
1913	118	134	0	134	− 1	137	− 2	134	− 2	145	+ 2	− 0.6
1914†	115	139	+ 5	139	+ 4	142	+ 3	140	+ 4	149	+ 6	+ 4.4
1915	117	133	− 1	135	0	138	− 1	136	0	144	+ 1	− 0.2
1916	108	135	+ 1	134	− 1	138	− 1	137	+ 1	143	0	0
1917	100	142	+ 8	139	+ 4	143	+ 4	142	+ 6	149	+ 6	+ 5.6
1918†	116	139	+ 5	138	+ 3	142	+ 3	142	+ 6	148	+ 5	+ 4.4
1919	100	140	+ 6	140	+ 5	144	+ 5	142	+ 6	150	+ 7	+ 5.8
1920	107	136	+ 2	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.6
1921	104	135	+ 1	133	− 2	137	− 2	134	− 2	133	−10	− 3.0
1922†	107	127	− 7	128	− 7	132	− 7	130	− 6	137	− 6	− 6.6
1923	125	125	− 9	126	− 9	134	− 5	130	− 6	142	− 1	− 6.0
1924	132	126	− 8	128	− 7	133	− 6	129	− 7	135	− 8	− 7.2
1925	127	133	− 1	134	− 1	139	0	137	+ 1	142	− 1	− 0.4
1916†	117	132	− 2	132	− 3	141	+ 2	140	+ 4	142	− 1	0
1917	114	141	+ 8	141	+ 6	149	+10	145	+ 9	148	+ 5	+ 7.6
1918	110	131	− 3	131	− 4	134	− 5	134	− 2	135	− 8	− 4.4
1919	103	134	0	134	− 1	141	+ 2	140	+ 4	141	− 2	+ 0.6
1920†	212	126	− 8	123	−12	131	− 8	129	− 7	137	− 6	− 8.2
1921	205	125	− 9	120	−15	127	−12	125	−11	133	−10	−11.4
1922	230	137	+ 3	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.8
1923	357	129	− 5	130	− 5	136	− 3	131	− 5	145	+ 2	− 3.2
1924†	305	139	+ 5	138	+ 3	144	+ 5	141	+ 5	149	+ 6	+ 4.8
1925	362	136	+ 2	134	− 1	138	− 1	135	− 1	143	0	− 0.2
Average 1891-1925	...	134	...	135	...	139	...	136	...	143	...	[137.4]
		My. 14		My. 15		My. 19		My. 16		My. 23		[My17]

† Leap years.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925.

Song-Thrush (*Turdus musicus*) first heard; Swallow (*Hirundo rustica*) first seen; Cuckoo (*Cuculus canorus*) first heard; Nightingale (*Daulias luscinia*) first heard; Flycatcher (*Muscicapa grisola*) first seen; Swallow (*Hirundo rustica*) last seen; Honey-Bee (*Apis mellifica*); Wasp (*Vespa vulgaris*); Small White Butterfly (*Pieris rapæ*); Orange-Tip Butterfly (*Anthocaris cardamines*); Meadow-Brown Butterfly (*Epinephile janira*); Humble Bee (*Bombus lapidarius*) first seen.

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
	Channel Isles: Guernsey. A.												
0a.	Les Blanches	1	88	108	...	...	298	...	...	109	...	166	*127*
0d.	Les Hubits	3	109	109	112	...	305	...	...	98	...	173	...
	A (8)												
1a.	Carbis Bay	2	102	108	...	...	290	78	...	88	...	...	...
1b.	St. Buryan	2	109	107	...	*153*	307	...	...	...	150	...	...
2c.	Mawgan	16	103	111	...	128	308	*103*	18	104	108	159	77
2d.	Mawnan	1	110	120	...	...	284	...	...	101	163	141	75
2e.	Devoran	1	115	109	...	...	...	...	...	102	...	...	...
*	Polperro	1	103	96	...	...	285	73	...	...	136	166	95
6a.	Duloe	9	97	110	...	*165*	285	17	...	...	93	*102*	...
9a.	Launceston	15	109	112	...	...	...	65	...	106	...	...	...
6c.	Lopwell	...	108	98	...	130	275	53	95	102	117	165	...
9c.	Clawton	2	110	122	...	139	...	92	...	106	...	...	...
10b.	Torquay	5	132	109	...	...	282	5	132	95	...	...	...
11c.	Spreyton	...	...	109	...	...	...	78	94	102	134	136	99
11d.	Copplestone	1	99	112	...	...	...	34	...	*132*	...	...	...
11e.	Bridestowe	10	117	109	...	145	276	...	98	118	134	...	...
12c.	Bradworthy	...	102	112	...	...	284	...	...	110	*49*	...	95
13a.	Exmouth	11	107	109	...	139	265	64	137	91	...	185	74
13c.	Exeter	1	97	109	...	146	254	...	...	102	...	...	...
14b.	Bish'p's Tawton	3	106	109	...	...	264	...	93	115	148	...	...
15a.	Buckerell	14	103	103	...	109	...	...	...	103	132	...	97
15b.	Colyford	...	106	109	...	...	...	97	...	97	142	155	...
†	Combe Martin	1	93	97	...	...	...	15	...	91	156	173	51
17e.	Ilfracombe	42	*158*	120	...	144	...	57	...	115	152	...	...
15c.	Lyme Regis	1	...	...	125	...	256	23	...	91	162	161	36
21c.	Sturminster Marshall	17	99	105	117	130	...	...	...	...	...	...	...
21d.	Broadstone	2	89	100	118	144	277	...	...	110	144	140	...
22a.	Pulham	3	113	101	121	149	283	101	...	...	163	...	...
24a.	Blandford	3	*78*	*78*	110	130	274	35	...	...	...	...	77
24d.	West Melbury	20	101	109	...	*178*	265	...	137	130	135	182	100
19c.	Bradney	1	104	115	114	...	...	...	...	101	...	...	...
19f.	Taunton	2	112	111	114	*113*	...	100	...	98	...	...	95
19g.	West Buckland	3	108	109	115	...	...	95	137	...	...	...	60
20a.	West Porlock	1	93	109	118	145	...	...	...	...	...	...	...
22c.	Street	1	98	107	114	...	276	...	82	...	...	...	...
22d.	Bruton	6	93	108	115	*113*	...	84	...	...	...	...	59
25b.	Flax Bourton	6	102	111	117	140	293	18	101	98	132	143	*143*
25c.	Keynsham	1	110	111	...	130	259	69	98	111	141	163	98

* Combination of 3 stations, 5a, b, c. † Combination of 3 stations 17a, b, d.
The dates in *italics* in Table VI. represent rejected values, and have not been taken into consideration when calculating the means for the Districts.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued*.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
27c. Portishead	2	102	108	127	...	278	63	127	101	100	165	98
28b. **Clevedon**	3	102	112	...	141	266	...	...	111	161	163	***144***
28d. **Llandaff**	2	93	109	...	130	276	...	...	...	...	...	...
29a. Bridgend	1	108	123	...	...	...	...	135	119	...	...	93
30a. Mumbles	2	113	109	...	136	296	32	132	98	134	165	...
32a/b. Tenby	11	109	117	...	...	277	...	...	91	...	...	98
33a. St. Davids	14	110	118	...	...	...	87	...	110	159	173	...
35a. Fishguard	44	93	116	...	...	...	8	...	100	...	...	60
34c. Philadelphia	18	101	110	...	...	289	...	...	...	99	...	93
36a. Llandilo	5	94	118	...	135	...	...	...	...	...	...	...
43a. Hafod	3	121	120	...	...	...	77	135	134	136	170	...
43c. **Aberystwyth**	10	108	110	...	137	275	...	121	97	130	159	77
B (10).												
6a. **Timoleague**	4	100	121	...	142	...	...	***158***	91	122	175	128
14a. Monkstown	2	100	...	...	...	290	...	...	...	...	...	...
14b. Passage West	7	113	128	...	...	***243***	...	...	116	***158***	172	...
22b. **Castle Lyons**	4	110	110	...	143	269	65	79	110	118	172	126
27a. Castleconnell	10	102	128	...	140	...	...	...	...	...	...	...
30a. Cashel	10	105	120	...	***174***	258	110	***157***	126	...	170	93
34b. Kilkenny	...	110	113	...	...	269	30	***134***	...	...	...	86
34d. Freshford	...	107	128	...	...	282	98	...	111	132	...	...
42a. Ballickmoyler	...	102	123	...	142	...	100	...	120	143	...	96
41a. Ferns	2	111	110	...	132	303	60	102	100	132	171	***144***
43a. Mountmellick	1	99	121	...	149	269	76	9	110	137	169	...
43b. Stradbally	32	109	110	...	...	277	...	***– 29***	...	129	...	...
49b. Dundrum	12	114	***141***	...	...	282	...	...	...	...	...	82
50a. Johnstown Bridge	...	114	124	...	...	275	76	...	110	148	...	76
C (5).												
4c. Salisbury	1	90	109	...	96	289	77	***139***	93	...	...	...
5b. Holt	23	100	107	...	...	277	53	...	...	...	...	...
5c. Bratton	1	110	112	120	132	286	...	...	...	...	...	...
8b. **Marlborough**	27	102	119	***148***	136	288	77	62	130	136	164	***131***
1a e. Bournemouth	3	102	118	...	...	276	67	67	...	...	...	...
1f. Boscombe	***48***	116	124	...	...	282	***117***	102	***132***	...	...	79
1b. Ringwood	1	106	109	113	...	279	59	...	***77***	133	...	...
1c. Lymington	1	108	108	119	153	313	60	111	84	133	...	101
1i. Appleslade, Ringwood	5	92	107	...	140	277	93	...	92	...	162	74
1d. Totland Bay	...	108	112	...	...	315	...	...	...	...	...	...
3a. Shanklin	4	96	110	115	124	305	...	84	100	132	154	100
3b. Newport	8	90	***85***	120	...	310	18	112	84	140	167	80
3e/f. Southsea	9	96	96	112	120	283	51	93	98	116	150	100
4b. Sherfield English	1	96	97	110	***164***	281	38	***152***	98	143	156	101
4d. Lyndhurst	...	103	109	119	...	273	...	...	...	...	...	...
6a. Havant	1	107	107	116	...	291	...	...	...	133	169	80
6d. Hayling Island	1	116	112	120	...	300	9	131	101	135	156	80

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly	Meadow-Brown Butterfly.	Humble Bee
7a. Botley	1	97	96	114	130	308	35	...	98	135	176	97
7b. West Meon	5	110	109	113	...	272	59	*137*	101	136	*100*	...
7c. Hythe, S'hampton	1	100	107	113	131	308	58	67	115	119	*117*	75
7f. Sutton Scotney	1	106	109	118	152	...	...	104	102	...	...	60
7h. Winchester	1	99	112	...	...	282	22	...	...	...	...	...
11b. Newton Valence, Alton	3	111	108	118	133	...	35	...	...	...	...	98
15k. Yateley	...	124	108	126	145	...	...	...	...	...	...	...
17c. Bradfield	6	116	100	*97*	...	...	...	35	...	...	...	...
20a. Reading	4	108	103	119	...	293	59	...	98	140	166	100
20c. Maidenhead	...	109	109	124	155	...	...	...	...	...	...	...
6c. Chichester	1	98	109	123	...	304	77	99	98	134	171	77
10a. Littlehampton	47	115	115	...	...	...	*114*	...	102	102	*112*	83
10b. Hove	5	118	115	...	140	279	74	119	110	132	145	85
10d. Portslade	1	100	108	105	128	293	62	78	106	133	154	73
15b/d. Horsham	1	104	107	111	116	273	35	93	95	113	153	114
15c. Steyning	...	...	...	...	...	...	...	...	115	118	160	74
18a. Lewes	1	100	109	114	130	312	67	135	101	133	164	116
18b. Hellingly	5	105	109	115	...	298	6	32	115	144	145	...
18c. Ditchling	2	100	110	*97*	121	295	43	12	86	116	177	67
21a. Brede	5	116	103	116	133	...	84	*137*	116	135	161	68
21b. Hastings	...	106	107	108	...	...	...	...	...	...	...	...
16b. Farnham	5	114	111	130	...	260	...	...	...	92	...	...
16g. Rowledge	1	113	108	115	135	...	66	*151*	129	...	...	*150*
16i. Churt	5	127	110	135	...	...	46	...	*133*	133	162	*137*
19a. Cranleigh	2	...	96	132	140	...	...	...	...	...	...	...
22a. Lingfield	3	109	108	135	137	273	75	*149*	119	137	180	69
22b. Warlingham	1	...	109	114	...	...	35	31	103	136	...	100
22c. Purley	1	112	98	120	...	276	94	126	122	136	180	101
22e. Limpsfield	...	121	108	116	...	...	...	...	...	...	...	...
24a. Lympne	1	112	112	116	...	...	...	...	116	...	...	...
24b. Woodchurch	5	108	97	112	...	315	...	...	*133*	119	...	100
25a/c Maidstone	10	112	100	102	...	...	...	...	101	137	...	...
25b. Mereworth	15	112	107	115	121	...	91	116	112	137	166	99
26a/c. Bromley	20	110	109	114	...	...	76	59	129	...	...	...
28a. Rochester	1	109	122	123	151	283	95	...	102	126	...	100
D (4)												
1b. Wotton-under-Edge	...	...	111	...	...	307	...	136	...	136	...	135
5b/c. Cheltenham	4	109	111	...	...	...	102	93	101	148	167	75
5d. Coaley	5	98	108	*141*	138	282	89	60	*154*	128	168	84
6a. Dymock	1	108	107	...	141	277	39	101	97	134	...	*142*
3b. Ross	5	117	115	...	144	...	74	...	102	...	...	...
4a. Weobley	...	...	109	...	...	274	66	...	116	154	...	111
4b. Staunton-on-Arrow	1	107	107	...	134	283	75	74	101	133	172	110
6b. Bromyard	9	121	111	...	...	291	...	...	...	...	...	...
6c. Kimbolton, Leominster	11	111	109	...	...	...	*133*	...	118	134	177	...

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued*.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
11b/c. Ludlow	36	118	110	...	...	...	99	...	136	136	149	...
17a. Edgmond	1	108	115	...	...	277	70	115	...	...	...	...
10b. Evesham	3	112	...	125	...	278	...	...	...	...	...	...
11a. Tenbury	1	100	108	128	135	276	72	102	102	131	165	119
16b. Wolverley, Cookley	1	111	113	133	142	271	...	...	98	...	...	89
16c. Barnt Green	2	101	111	...	136	...	36	119	...	...	...	...
10c. Ashorne	14	110	111	...	...	285	...	99	111	153	...	...
15a. Whernalls	...	108	110	113	133	...	...	...	...	...	...	...
15c. Stratford-on-Avon	5	111	109	115	141	269	94	144	100	136	161	101
16d. Quinton	19	110	119	...	...	270	59	130	132	135	146	107
16e. South Birmingham	8	98	108	...	129	274	...	...	132	144	175	...
20a. Farnborough	3	105	114	...	128	269	72	98	115	144	180	*153*
21b. Erdington	4	115	114	...	...	...	102	...	107	...	...	...
21d. Hampton-on-the-Hill	3	113	108	122	...	...	74	...	...	...	...	...
21e. Leamington Spa	3	108	116	...	...	...	...	...	...	140	...	...
21f. Hall Green	3	102	122	...	...	258	...	...	...	...	...	...
21g. King's Heath	...	109	118	...	...	...	101	101	*157*	...	179	...
26b. Sutton Coldfield	1	108	113	...	142	296	110	...	...	...	...	...
14a/b Oxford	11	103	108	122	...	276	90	...	102	...	...	98
19a. Weston Turville	...	115	109	...	...	269	...	...	...	...	158	...
19b. Granborough	1	109	113	...	127	274	74	97	101	133	...	93
24a. Bletchley	9	114	114	*141*	...	273	63	104	112	135	...	117
24b. Northampton	1	110	112	134	...	274	75	...	102	...	...	...
33a. Ketton	*79*	112	120	121	137	...	72	...	99	132	...	...
25a. Mowsley	5	101	117	...	135	...	...	...	...	...	...	...
34a. Kegworth	3	113	112	...	...	295	74	92	101	153	156	103
35a. Somersal Herbert	11	101	120	...	125	...	*146*	64	102	131	180	...
35b. Matlock.	16	110	121	...	125	269	...	...	...	...	...	...
37b. Balderton	18	112	*136*	...	...	...	...	...	...	136	168	101
38a. Hodsock	8	106	110	...	135	276	51	123	133	...	190	...
39a. Huddersfield	6	132	118	...	...	...	67	138	137	...	...	131
39b. Kirkheaton	55	96	96	...	...	260	*134*	...	136	...	...	...
39c. Thurlstone	10	120	121	...	...	270	86	*145*	121	*166*	...	*169*
41c. Grindleton	19	119	129	...	124	...	...	*144*	...	...	...	*146*
41d. Crosshills	17	100	117	...	...	286	72	...	130	...	...	99
44a. Sitwell Vale	12	130	...	...	...	272	104	...	134	...	...	...
44b. Newhill, Wath	11	110	123	...	...	274	...	136	133	...	...	...
45a. Middlestown	15	118	113	...	...	270	101	130	136	...	...	...
45b. Altofts	25	120	117	...	...	...	...	...	...	...	...	...
49b. Fairburn	17	110	123	...	...	294	...	...	133	...	...	...
E (3)												
1c. Barnet	7	99	109	...	123	282	100	...	100	136	...	101
1d. Whetstone	16	109	111	...	132	...	48	102	102	...	...	114
2a. Berkhamsted	6	104	112	*142*	*181*	...	72	126	102	*168*	136	135

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued*.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
2b. Tring	48	100	100	119	...	313	...	...	111	131	...	...
4b. Knebworth	14	97	107	109	...	...	30	...	...	...	...	100
4c/l Harpenden	5	108	109	123	134	273	39	...	...	135	181	133
4i. Hitchin	2	99	97	100	132	305	23	...	102	...	169	99
4k. Pirton, Hitchin	27	102	111	...	...	274	99	137	127	137	171	107
7b. Sawbridgeworth	1	99	108	121	130	309	23	133	119	133	163	95
7f. Buntingford	8	107	100	...	*96*	282	64	98	109	138	104	111
* Letchworth	1	99	94	100	...	290	17	54	101	119	136	101
5a. Turvey	3	100	113	118	140	291	46	130	101	132	155	101
8a. Kempston	1	110	115	...	132	275	68	...	101	109	...	...
10a. Maldon	6	109	116	111	...	274	102	*146*	99	138	171	102
10b. Halstead	6	111	112	...	...	283	60	...	103	132	165	...
10d. Tolleshunt Knights	13	109	114	115	...	285	...	...	...	...	...	...
10f. Great Totham	20	109	110	117	...	288	34	93	119	115	77	84
13a. Lexden	14	103	109	116	139	297	75	98	...	134	174	...
13b. Colchester	...	102	117	121	...	...	...	129	103	133	...	...
11d. Cambridge	1	108	113	115	129	273	*135*	...	...	131	...	*143*
14a. Ballingdon	3	111	113	113	135	291	79	98	111	137	164	77
17a. Belstead, Ipswich	11	102	105	115	125	...	...	...	...	...	...	...
17c. Ipswich	...	107	122	122	129	...	...	...	...	...	...	...
17d. Bramford, Ipswich	...	107	113	122	...	...	...	...	110	...	...	...
23a. Bungay	5	115	130	...	...	274	80	92	112	140	148	92
22b. Langford	3	100	110	115	...	278	60	132	112	132	165	98
24b. Postwick	1	*136*	102	...	...	248	88	115	94	...	...	83
25a. Hunstanton	9	98	111	...	128	273	...	...	113	151	...	95
F (7)												
9a. Beaumaris	3	104	125	...	142	264	97	128	125	163	...	*164*
9b. Deganwy	4	108	114	...	*150*	269	...	...	...	...	...	74
10a. Wrexham	16	115	120	...	142	...	...	...	...	...	...	...
11d. Trefnant	2	108	121	...	...	...	97	98	102	...	...	...
13c. Higher Tranmere	7	117	123	...	...	...	...	137	111	...	...	96
13d. Shotwick	15	109	110	...	122	283	98	135	134	136	161	*134*
14a. Barnton	3	101	110	...	...	275	71	100	122	132	*196*	97
14b. Altrincham	1	114	115	...	132	263	*130*	135	136	...	...	...
16a. Prestbury	...	111	124	...	...	270	99	96	137	...	...	109
16b. Bramhall	21	106	116	...	140	278	37	103	107	...	171	102
18a. Blackpool	24	*138*	124	...	138	*261*	...	...	118	...	166	132
19a. Stockport	20	108	114	...	...	279	117	113	121	139	143	92
21a. Leyland	3	110	129	...	...	258	...	...	...	...	172	...
21b. Ashton-on-Ribble	10	120	120	...	...	...	102	*158*	123	152	*136*	100
22a. Urswick	*59*	103	114	...	...	274	97	*155*	97	157	184	*174*
22b. Ulverston	3	113	126	...	131	298	...	...	...	...	...	...

* Combination of 3 stations 8a, b, c.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
22d. Grange over-Sands	...	...	...	...	...	...	...	...	92	134	165	...
25a. Ambleside	15	100	119	...	140	284	63	...	136	146	...	...
28b. Johnby Hall	49	135	142	...	...	261	130	137	*155*	...	...	...
28c. Mungrisdale	20	116	119	...	132	264	...	...	...	...	...	102
31a. Kelsick	3	111	122	...	...	254	...	101	110	137	175	133
32a. Alston	...	110	121	...	127	291	...	...	...	182	...	...
G (9)												
18 a. Longford	12	114	115	...	...	302	101	121	114	130	157	...
41a. Bessbrook	10	110	122	...	137	302	79	115	115	137	189	...
41c. Scarva	12	107	*148*	...	...	...	111	...	113	121	...	120
35c. Warrenpoint	7	97	122	...	125	295	...	121	98	129	157	77
35d. Rostrevor	9	109	118	...	...	273	110	104	110	137	175	*134*
50a. Hillsborough	4	109	110	...	155	276	...	104	143	155	...	...
47a. Sixtowns	11	110	121	...	...	271	...	...	...	137	184	...
51a. Magherafelt	1	111	121	...	...	255	112	117	149	149	152	*152*
48b. Milford	*50*	109	115	...	...	...	98	...	130	...	...	110
50c. Belfast	11	*70*	120	...	...	277	...	...	...	...	...	...
50d. Muckamore	7	114	128	...	...	270	.	...	...	...	...	...
50f. Woodburn	24	112	109	...	...	*246*	...	*169*	*154*	...	*116*	109
54a. Hazelbank	5	98	112	...	...	284	60	103	103	137	153	100
55a. Ballymoney	3	109	119	...	...	265	104	...	130	130	...	*140*
H Isle of Man:												
6a. Douglas*	35	99	...	...	142	*315*	...	...	...	...	...	...
H (6).												
1a. Kirkmaiden	18	110	122	...	...	271	60	123	117	122	147	103
2a. Marks	15	109	121	...	...	...	96	96	119	...	...	...
27b. Larkhall	17	118	102	...	...	271	74	65	130	...	...	74
33a. Ledaig, Oban	16	120	121	...	...	...	*135*	119	136	...	...	...
I (2).												
5b. Kirton, Boston	9	111	114	...	138	270	102	82	102	151	...	*131*
9a. Woodhall Spa	...	111	120	120	...	...	...	...	...	146	...	...
9a. Ashby	13	110	117	...	...	...	62	...	111	...	...	...
10a. West Keal	17	121	110	...	142	264	35	*134*	...	138	...	*153*
11b. ThorntonAbbey	8	101	116	...	...	291	...	...	...	163	...	104
11d. Cleethorpes	16	104	106	...	...	...	108	123	117	...	...	...
20a. Louth	18	116	110	...	...	...	...	100	102	...	179	102
12a. Howdenshire	10	102	115	...	145	...	...	...	...	...	...	...
16a. Whitaside	35	132	124	...	...	...	...	130	...	...	...	*136*
18a. Middleton-in-Teesdale	38	96	116	...	...	287	38	133	131	...	*129*	...
21a. Hull	3	120	126	...	...	302	101	118	110	140	160	94
23a. Thirsk	10	96	122	...	140	275	73	113	132	160	...	...
27a. Withernsea	15	105	97	...	...	268	*140*	..	*187*	*171*	...	104
24b. Darlington	18	103	121	...	...	270	...	9	130	143	167	...
33a. Lanchester	25	112	116	...	...	268	100	2	101	...	...	114

* Not included in the means for District H.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
33b. Chopwell	34	113	122	...	*122*	285	87	74	115	...	173	85
33c. Chester-le-Street	...	133	135	...	...	...	...	133	135	...	...	118
33f. North Shields*	...	136	129	...	...	277	...	...	...	...	...	...
19a. Haltwhistle	24	102	122	...	130	289	...	...	...	...	...	...
25a/c Corbridge	12	111	123	...	...	...	74	...	146	...	...	...
25b. Stocksfield	...	116	129	...	...	263	...	...	139	...	...	109
25d. Allendale	42	111	124	...	...	...	...	129	136	...	...	99
26a. Catcleugh	17	111	122	...	140	275	...	132	128	...	...	...
36a. Seaton Delaval	17	127	124	...	...	...	...	...	124	...	...	...
38a. Embleton	17	...	...	...	134	262	102	92	...	...	...	...
38b. Belford	21	111	123	...	*165*	282	100	*162*	...	134	...	81
38c. Lemmington	12	107	124	...	153	283	109	117	110	117	169	*63*
39a. Berwick	5	115	135	...	...	268	100	*146*	146	...	...	*139*
J (1).												
6b. Jedburgh	11	112	136	...	...	272	102	133	...	...	...	125
4a. Selkirk	12	109	122	...	144	275	...	...	...	...	...	...
6a. Galashiels	17	113	122	...	...	264	52	*161*	...	...	...	97
2a. Broughton	16	116	121	...	133	278	74	101	139	...	...	...
10a. West Foulden	11	109	114	...	...	283	...	111	137	...	180	...
13a. Stirling	10	111	120	...	141	257	50	139	...	...	...	85
20a. TummelBridge	27†	...	124	...	139	269	...	...	...	...	...	...
35b. South Fowlis	...	125	122	...	127	255	*11*	*147*	139	...	...	130
36a. Cabrach	65	120	122	...	...	263	100	129	154	163	181	126
39a. Dunlugas	61	129	121	...	124	273	76	128	153	169	179	95
39b. Forglen	47	124	126	...	136	...	65	138	...	...	...	112
40b. Kellas	...	119	116	...	...	...	...	134	128	...	...	...
K (0).												
27b. Kirkhill	47	127	125	...	...	266	*140*	142	150	...	156	101
24b. Muir of Ord	28	132	125	...	...	...	63	...	...	...	...	108
33a. Golspie	20	123	125	...	...	...	...	...	...	...	...	101
Total Records Used	271	359	366	103	120	201	172	138	209	150	112	137

* Received too late for inclusion in means. † Observed at Aberfeldy, 10 miles S.

(*Continued from page* 297.)

Second Flowering was also less noted. A6a, field rose, *R. arvensis*, in Nov.; elsewhere, fruit trees in Oct., result of June drought; so lilac, black currant, laburnum, holly. At B50a, "some apples kept on all the year."

Fruiting. Tree fruits failed as a rule in part or whole; berries did better, unaffected by earlier drought. Acorn and mast fared badly and hazel nuts as a rule. All report pear failure; A9b, "worst ever known"; plums little better; apples coloured well but were bad keepers, often

(*Continued on page* 314.)

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TABLE VIA.—MEAN DATES (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS IN 1925, AND DIFFERENCE FROM THE AVERAGE OF THE 35 YEARS, 1891–1925.

BIRDS AND INSECTS.	Channel Islands 1925.	A (8) England, S.W.				B (10) Ireland, S.				C (5) England, S.E.				D (4) England, Mid.				E (3) England, E.				F (7) England, N.W.			
		1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.
1. Song Thrush First Heard	2	7	15	− 8	16	9	12	− 3	13	6	14	− 8	15	9	19	−10	20	9	16	− 7	16	12	24	− 12	26
2. Swallow First Seen	(99)	105	105	0	105	106	105	+ 1	104	106	105	+ 1	106	109	109	0	109	104	109	− 5	109	110	110	0	110
3. Cuckoo First Heard	109	110	111	− 1	111	120	116	+ 4	115	109	107	+ 2	107	113	112	+ 1	112	110	111	− 1	111	120	117	+ 3	117
4. Nightingale First Heard	[112]	117	120	− 3	120	...	...	...	...	117	112	+ 5	111	123	117	+ 6	116	114	114	0	113	...	122	...	122
5. Spotted Flycatcher First Seen	...	137	134	+ 3	134	141	135	+ 6	135	133	132	+ 1	132	134	135	− 1	136	131	135	− 4	136	135	131	+ 4	131
6. Swallow Last Seen	(301)	279	282	− 3	283	275	279	− 4	281	280	292	− 3	292	277	282	− 5	283	284	289	− 5	291	273	279	− 6	279
Mean of Nos. 2, 3 and 5	...	117	117	0	117	122	119	+ 3	118	116	115	+ 1	115	119	119	0	119	115	118	− 3	119	122	119	+ 3	119
7. Honey Bee at Flowers	...	58	58	0	58	77	61	+16	58	60	56	+ 4	55	79	59	+20	56	58	53	+ 5	52	92	65	+ 27	62
8. Queen Wasp on Wing	...	110	96	+14	95	63	99	−36	99	94	94	0	94	105	101	+ 4	101	103	94	+ 9	94	117	105	+ 12	104
9. Small White Butterfly	(103)	106	102	+ 4	102	110	108	+ 2	107	105	103	+ 2	103	116	112	+ 4	111	107	107	0	107	115	114	+ 1	112
10. Orange-Tip Butterfly	...	139	127	+12	127	133	121	+12	120	130	127	+ 3	128	138	133	+ 5	133	133	132	+ 1	133	147	136	+ 11	135
11. Meadow Brown Butterfly	(169)	161	160	+ 1	161	171	146	+25	146	162	164	− 2	165	168	167	+ 1	167	150	167	−17	167	167	170	− 3	170
12. Humble Bee	...	81	...	...	...	98	...	...	...	87	...	...	...	104	...	...	...	102	...	...	...	104	...	...	...
Mean of Nos. 7-11	...	115	109	+ 6	109	111	107	+ 4	106	110	109	+ 1	109	121	114	+ 7	114	110	111	− 1	111	128	118	+ 10	117

BIRDS AND INSECTS.	G (9) Ireland, N.				H (6) Scotland, W.				I (2) England, N.E.				J (1) Scotland, E.				K (0) Scotland, N.				England and Wales.*				British Isles.†			
	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.
1. Song Thrush	9	20	− 11	22	17	29	−12	31	19	30	−11	31	27	28	− 1	28	35	41	− 6	42	10	19	− 9	21	14	23	− 9	24
2. Swallow First Seen	110	108	+ 2	108	115	113	+ 2	114	112	114	− 2	114	115	118	− 3	118	125	126	− 1	126	108	109	− 1	109	111	111	0	111
3. Cuckoo	120	118	+ 2	119	117	120	− 3	120	119	119	0	119	123	123	0	124	126	125	+ 1	126	113	113	0	113	117	116	+ 1	117
4. Nightingale	...	(129)	...	129	...	...	...	...	[120]	120	[0]	116	...	...	...	...	...	...	...	...	118	117	+ 1	116	‡124	‡125	− 1	‡124
5. Spotted Flycatcher	130	137	+ 2	137	...	140	...	137	140	135	+ 5	135	135	139	− 4	139	...	158	...	159	135	134	+ 1	134	136	137	− 1	137
6. Swallow Last Seen	279	275	+ 4	275	(271)	275	(−4)	277	277	279	− 2	280	260	270	− 1	270	[266]	260	[+6]	261	280	284	− 4	285	276	278	− 2	279
Mean of Nos. 2, 3 and 5	123	121	+ 2	121	...	124	...	124	124	123	+ 1	123	124	127	− 3	127	...	136	...	137	119	119	0	119	121	121	0	122
7. Honey Bee	93	73	+ 20	71	73	72	+ 1	71	85	64	+21	61	74	68	+ 6	69	[63]	66	[−3]	63	72	59	+13	57	74	63	+ 11	61
8. Queen Wasp	112	109	+ 3	108	104	121	−17	122	112	111	+ 1	111	124	117	+ 7	118	[142]	120	[+22]	122	107	100	+ 7	100	108	106	+ 2	106
9. Small White Butterfly	121	115	+ 6	115	123	124	− 1	123	124	119	+ 5	119	140	129	+11	129	[150]	134	[+16]	136	112	109	+ 3	109	120	115	+ 5	115
10. Orange-Tip Butterfly	130	130	+ 9	129	[122]	131	[−9]	136	144	143	+ 1	143	156	151	+ 5	151	...	*148*	...	*148*	139	133	+ 6	133	138	135	+ 3	135
11. Meadow Brown B'fly	167	165	+ 2	166	[147]	167	[−20]	171	170	167	+ 3	168	180	175	+ 5	174	[156]	*172*	*[−16]*	*172*	163	167	− 4	167	164	165	− 1	166
12. Humble Bee	103	...	...	...	89	...	...	...	101	...	...	...	109	...	...	...	106	...	...	...	97	...	...	...	99	...	...	...
Mean of Nos. 7-11	126	118	+ 8	118	114	123	− 9	125	127	121	+ 6	120	135	128	+ 7	128	...	128	...	128	119	114	+ 5	113	120	117	+ 3	117

* Average of districts A, C, D, E, F, I. † The British Isles means in both Tables (VIA and VII) are the means of the separate districts. ‡ The difference between the dates for the Nightingale and the Cuckoo in those districts in which *both* have been recorded, has been used as a basis for deriving the British Isles means for Nightingale. ( ) Show means of two observations only. [ ] One observation only. Values in *italics* have been interpolated owing to lack of data and are approximate only.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
33b. Chopwell	34	113	122	...	*122*	285	87	74	115	...	173	85
33c. Chester-le-Street	...	133	135	...	...	...	...	133	135	...	...	118
33f. North Shields*	...	136	129	...	...	277	...	...	...	...	...	...
19a. Haltwhistle	24	102	122	...	130	289	...	...	...	...	...	...
25a/c Corbridge	12	111	123	...	...	...	74	...	146	...	...	...
25b. Stocksfield	...	116	129	...	...	263	...	...	139	...	...	109
25d. Allendale	42	111	124	...	...	...	...	129	136	...	...	99
26a. Catcleugh	17	111	122	...	140	275	...	132	128	...	...	...
36a. Seaton Delaval	17	127	124	...	...	...	...	...	124	...	...	...
38a. Embleton	17	...	...	...	134	262	102	92	...	...	...	...
38b. Belford	21	111	123	...	*165*	282	100	*162*	...	134	...	81
38c. Lemmington	12	107	124	...	153	283	109	117	110	117	169	*63*
39a. Berwick	5	115	135	...	...	268	100	*146*	146	...	...	*139*
J (1).												
6b. Jedburgh	11	112	136	...	...	272	102	133	...	...	...	125
4a. Selkirk	12	109	122	...	144	275	...	...	...	...	...	...
6a. Galashiels	17	113	122	...	...	264	52	*161*	...	...	...	97
2a. Broughton	16	116	121	...	133	278	74	101	139	...	...	...
10a. West Foulden	11	109	114	...	...	283	...	111	137	...	180	...
13a. Stirling	10	111	120	...	141	257	50	139	...	...	...	85
20a. TummelBridge	27†	...	124	...	139	269	...	...	...	...	...	...
35b. South Fowlis	...	125	122	...	127	255	*11*	*147*	139	...	...	130
36a. Cabrach	65	120	122	...	...	263	100	129	154	163	181	126
39a. Dunlugas	61	129	121	...	124	273	76	128	153	169	179	95
39b. Forglen	47	124	126	...	136	...	65	138	...	...	...	112
40b. Kellas	...	119	116	...	...	...	...	134	128	...	...	...
K (0).												
27b. Kirkhill	47	127	125	...	...	266	*140*	142	150	...	156	101
24b. Muir of Ord	28	132	125	...	...	...	63	...	...	...	...	108
33a. Golspie	20	123	125	...	...	...	...	...	...	...	...	101
Total Records Used	271	359	366	103	120	201	172	138	209	150	112	137

* Received too late for inclusion in means. † Observed at Aberfeldy, 10 miles S.

(*Continued from page* 297.)

Second Flowering was also less noted. A6a, field rose, *R. arvensis*, in Nov.; elsewhere, fruit trees in Oct., result of June drought; so lilac, black currant, laburnum, holly. At B50a, "some apples kept on all the year."

Fruiting. Tree fruits failed as a rule in part or whole; berries did better, unaffected by earlier drought. Acorn and mast fared badly and hazel nuts as a rule. All report pear failure; A9b, "worst ever known"; plums little better; apples coloured well but were bad keepers, often

(*Continued on page* 314.)

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TABLE VIA. MEAN DATES (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS IN 1925, AND DIFFERENCE FROM THE AVERAGE OF THE 35 YEARS, 1891–1925.

BIRDS AND INSECTS.	Channel Islands 1925.	A (8) England, S.W. 1925.	A (8) England, S.W. Average 35 years.	A (8) England, S.W. Difference from 35-year Average.	A (8) England, S.W. Average 30 years.	B (10) Ireland, S. 1925.	B (10) Ireland, S. Average 35 years.	B (10) Ireland, S. Difference from 35-year Average.	B (10) Ireland, S. Average 30 years.	C (5) England, S.E. 1925.	C (5) England, S.E. Average 35 years.	C (5) England, S.E. Difference from 35-year Average.	C (5) England, S.E. Average 30 years.	D (4) England, Mid. 1925.	D (4) England, Mid. Average 35 years.	D (4) England, Mid. Difference from 35-year Average.	D (4) England, Mid. Average 30 years.	E (3) England, E. 1925.	E (3) England, E. Average 35 years.	E (3) England, E. Difference from 35-year Average.	E (3) England, E. Average 30 years.	F (7) England, N.W. 1925.	F (7) England, N.W. Average 35 years.	F (7) England, N.W. Difference from 35-year Average.	F (7) England, N.W. Average 30 years.
1. Song Thrush First Heard	2	7	15	− 8	16	9	12	− 3	13	6	14	− 8	15	9	19	−10	20	9	16	− 7	16	12	24	− 12	26
2. Swallow First Seen	(99)	105	105	0	105	106	105	+ 1	104	106	105	+ 1	106	109	109	0	109	104	109	− 5	109	110	110	0	110
3. Cuckoo First Heard	109	110	111	− 1	111	120	116	+ 4	115	109	107	+ 2	107	113	112	+ 1	112	110	111	− 1	111	120	117	+ 3	117
4. Nightingale First Heard	[112]	117	120	− 3	120	...	...	...	...	117	112	+ 5	111	123	117	+ 6	116	114	114	0	113	...	122	...	122
5. Spotted Flycatcher First Seen	...	137	134	+ 3	134	141	135	+ 6	135	133	132	+ 1	132	134	135	− 1	136	131	135	− 4	136	135	131	+ 4	131
6. Swallow Last Seen	(301)	279	282	− 3	283	275	279	− 4	281	289	292	− 3	292	277	282	− 5	283	284	289	− 5	291	273	279	− 6	279
Mean of Nos. 2, 3 and 5	...	117	117	0	117	122	119	+ 3	118	116	115	+ 1	115	119	119	0	119	115	118	− 3	119	122	119	+ 3	119
7. Honey Bee at Flowers	...	58	58	0	58	77	61	+16	58	60	56	+ 4	55	79	59	+20	56	58	53	+ 5	52	92	65	+ 27	62
8. Queen Wasp on Wing	...	110	96	+14	95	63	99	−36	99	94	94	0	94	105	101	+ 4	101	103	94	+ 9	94	117	105	+ 12	104
9. Small White Butterfly	(103)	106	102	+ 4	102	110	108	+ 2	107	105	103	+ 2	103	116	112	+ 4	111	107	107	0	107	115	114	+ 1	112
10. Orange-Tip Butterfly	...	139	127	+12	127	133	121	+12	120	130	127	+ 3	128	138	133	+ 5	133	133	132	+ 1	133	147	136	+ 11	135
11. Meadow Brown Butterfly	(169)	161	160	+ 1	161	171	146	+25	146	162	164	− 2	165	168	167	+ 1	167	150	167	−17	167	167	170	− 3	170
12. Humble Bee	...	81	...	...	...	98	...	...	...	87	...	...	...	104	...	...	...	102	...	...	...	104	...	...	...
Mean of Nos. 7-11	...	115	109	+ 6	109	111	107	+ 4	106	110	109	+ 1	109	121	114	+ 7	114	110	111	− 1	111	128	118	+ 10	117

BIRDS AND INSECTS.	G (9) Ireland, N. 1925.	G (9) Ireland, N. Average 35 years.	G (9) Ireland, N. Difference from 35-year Average.	G (9) Ireland, N. Average 30 years.	H (6) Scotland, W. 1925.	H (6) Scotland, W. Average 35 years.	H (6) Scotland, W. Difference from 35-year Average.	H (6) Scotland, W. Average 30 years.	I (2) England, N.E. 1925.	I (2) England, N.E. Average 35 years.	I (2) England, N.E. Difference from 35-year Average.	I (2) England, N.E. Average 30 years.	J (1) Scotland, E. 1925.	J (1) Scotland, E. Average 35 years.	J (1) Scotland, E. Difference from 35-year Average.	J (1) Scotland, E. Average 30 years.	K (0) Scotland, N. 1925.	K (0) Scotland, N. Average 35 years.	K (0) Scotland, N. Difference from 35-year Average.	K (0) Scotland, N. Average 30 years.	England and Wales.* 1925.	England and Wales.* Average 35 years.	England and Wales.* Difference from 35-year Average.	England and Wales.* Average 30 years.	British Isles.† 1925.	British Isles.† Average 35 years.	British Isles.† Difference from 35-year Average.	British Isles.† Average 30 years.
1. Song Thrush	9	20	− 11	22	17	29	−12	31	19	30	−11	31	27	28	− 1	28	35	41	− 6	42	10	19	− 9	21	14	23	− 9	24
2. Swallow First Seen	110	108	+ 2	108	115	113	+ 2	114	112	114	− 2	114	115	118	− 3	118	125	126	− 1	126	108	109	− 1	109	111	111	0	111
3. Cuckoo	120	118	+ 2	119	117	120	− 3	120	119	119	0	119	123	123	0	124	126	125	+ 1	126	113	113	0	113	117	116	+ 1	117
4. Nightingale	...	120	...	129	...	...	...	...	[120]	120	[0]	116	...	...	...	...	...	...	...	...	118	117	+ 1	116	‡124	‡125	− 1	‡124
5. Spotted Flycatcher	130	137	+ 2	137	...	140	...	137	140	135	+ 5	135	135	139	− 4	139	...	158	...	159	135	134	+ 1	134	136	137	− 1	137
6. Swallow Last Seen	279	275	+ 4	275	(271)	275	(−4)	277	277	279	− 2	280	269	270	− 1	270	[266]	260	[+6]	261	280	284	− 4	285	276	278	− 2	279
Mean of Nos. 2, 3 and 5	123	121	+ 2	121	...	124	...	124	124	123	+ 1	123	124	127	− 3	127	...	136	...	137	119	119	0	119	121	121	0	122
7. Honey Bee	93	73	+ 20	71	73	72	+ 1	71	85	64	+21	61	74	68	+ 6	69	[63]	66	[−3]	63	72	59	+13	57	74	63	+ 11	61
8. Queen Wasp	112	109	+ 3	108	104	121	−17	122	112	111	+ 1	111	124	117	+ 7	118	[142]	120	[+22]	122	107	100	+ 7	100	108	106	+ 2	106
9. Small White Butterfly	121	115	+ 6	115	123	124	− 1	123	124	119	+ 5	119	140	129	+11	129	[150]	134	[+16]	136	112	109	+ 3	109	120	115	+ 5	115
10. Orange-Tip Butterfly	130	130	+ 9	129	[122]	131	[−9]	136	144	143	+ 1	143	156	151	+ 5	151	...	*148*	...	*148*	139	133	+ 6	133	138	135	+ 3	135
11. Meadow Brown B'fly	167	165	+ 2	166	[147]	167	[−20]	171	170	167	+ 3	168	180	175	+ 5	174	[156]	*172*	[−16]	*172*	163	167	− 4	167	164	165	− 1	166
12. Humble Bee	103	...	...	...	89	...	...	...	101	...	...	...	109	...	...	...	106	...	...	...	97	...	...	...	99	...	...	...
Mean of Nos. 7-11	126	118	+ 8	118	114	123	− 9	125	127	121	+ 6	120	135	128	+ 7	128	...	128	...	128	119	114	+ 5	113	120	117	+ 3	117

* Average of districts A, C, D, E, F, I. † The British Isles means in both Tables (VIA and VII) are the means of the separate districts. ‡ The difference between the dates for the Nightingale and the Cuckoo in those districts in which *both* have been recorded, has been used as a basis for deriving the British Isles means for Nightingale. ( ) Show means of two observations only. [ ] One observation only. Values in *italics* have been interpolated owing to lack of data and are approximate only.

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TABLE IV.—Mean Dates (Day of Year) for the Flowering of Fourteen Plants in 1925 and Difference from the Average of the 35 Years 1891-1925.

Plants.	Channel Isles 1926.	A (8) England, S.W.				B (10) Ireland, S.				C (5) England, S.E.				D (4) England, Mid.				E (3) England, E.				F (7) England, N.W.			
		1926.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1926.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1926.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1926.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1926.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1924.	Average 35 years.	Difference from 35-year Average.	Average 30 years.
1. *Corylus avellana*	[53]	37	38	− 1	39	46	33	+13	32	30	32	− 2	33	34	41	− 7	41	31	35	− 4	36	45	43	+ 2	43
2. *Tussilago farfara*	...	53	55	− 2	55	57	58	− 1	59	46	58	−12	60	54	63	− 9	64	44	61	−17	62	52	62	−10	64
3. *Anemone nemorosa*	...	83	84	− 1	85	76	77	− 1	79	79	82	− 3	82	84	89	− 5	90	86	88	− 2	88	90	90	± 0	91
4. *Prunus spinosa*	121	86	89	− 3	91	92	82	+10	83	89	94	− 5	94	93	99	− 6	100	92	96	− 4	97	103	102	+ 1	102
5. *Sisymbrium alliaria*	(123)	113	107	+ 6	107	113	112	+ 1	113	113	110	+ 3	110	117	113	+ 4	113	116	111	+ 5	112	121	122	− 1	122
6. *Æsculus hippocastanum*	(123)	130	122	+ 8	122	129	123	+ 6	123	131	126	+ 5	126	135	130	+ 5	130	132	126	+ 6	126	135	132	+ 3	132
7. *Cratægus oxyacantha*	(127)	137	130	+ 7	130	139	131	+ 8	131	135	130	+ 5	131	137	133	+ 4	134	133	131	+ 2	131	140	138	+ 2	138
8. *Chrysanthemum leucanthemum*	[115]	148	145	+ 3	145	150	144	+ 6	144	145	141	+ 4	141	153	149	+ 4	148	145	145	± 0	145	154	154	± 0	153
9. *Rosa canina*	(163)	160	155	+ 5	155	163	158	+ 5	158	156	155	+ 1	155	161	159	+ 2	158	154	155	− 1	156	162	162	± 0	162
10. *Centaurea nigra*	(197)	175	172	+ 3	172	193	184	+ 9	183	170	171	− 1	171	179	177	+ 2	177	179	177	+ 2	177	189	189	± 0	189
11. *Campanula rotundifolia*	...	192	193	− 1	193	(201)	185	(+16)	184	190	186	+ 4	185	190	191	− 1	190	191	189	+ 2	189	194	188	+ 6	187
12. *Convolvulus sepium*	(176)	183	186	− 3	187	202	192	+10	192	186	187	− 1	187	188	191	− 3	191	190	190	± 0	191	198	196	+ 2	195
13. *Hedera helix*	(258)	267	264	+ 3	263	266	263	+ 3	262	269	269	± 0	269	266	268	− 2	268	264	266	− 2	265	275	277	− 2	277
14. *Scabiosa succisa*	...	212	...	...	...	210	...	...	...	227	...	...	...	217	...	...	...	224	...	...	...	220	...	...	...
Mean of Plants 1-13	...	136	134	+ 2	134	141	134	+ 7	134	134	135	+ 1	134	138	139	− 1	139	135	136	− 1	137	143	143	± 0	143
Mean of Plants 1-14	...	141	...	...	...	145	...	...	...	140	...	...	...	143	...	...	...	141	...	...	...	148	...	...	...

	G (9) Ireland, N.				H (6) Scotland, W.				I (2) England, N.E.				J (1) Scotland, E.				K (0) Scotland, N.				England and Wales.*				British Isles. †			
1. Hazel	45	48	− 3	49	42	49	− 7	47	39	46	− 7	48	58	55	+ 3	55	[43]	50	[− 7]	48	36	39	− 3	40	41	44	− 3	44
2. Coltsfoot	50	67	−17	69	68	67	+ 1	69	52	64	−12	66	77	73	+ 4	73	[89]	76	[+13]	74	50	60	−10	62	58	64	− 6	65
3. Wood Anemone	81	88	− 7	88	95	97	− 2	97	98	93	+ 5	93	103	104	− 1	104	(105)	107	(− 2)	107	87	88	− 1	88	89	91	− 2	92
4. Blackthorn	105	100	+ 5	101	101	112	−11	114	103	107	− 4	108	119	116	+ 3	116	[129]	115	[+14]	115	94	98	− 4	98	101	101	± 0	102
5. Garlic Hedge-Mustard	117	112	+ 5	110	(119)	127	(− 8)	127	120	121	− 1	121	128	128	± 0	128	[137]	128	[+ 9]	128	117	114	+ 3	114	119	119	± 0	120
6. Horse-Chestnut	139	131	+ 8	131	(129)	142	(−13)	142	139	138	+ 1	139	149	145	+ 4	145	(129)	142	(−13)	143	134	129	+ 5	129	134	133	+ 1	133
7. Hawthorn	143	138	+ 5	138	141	145	− 4	145	142	139	+ 3	140	151	148	+ 3	148	(129)	152	(−23)	152	137	133	+ 4	134	139	139	± 0	139
8. White Ox-Eye	162	155	+ 7	155	152	160	− 8	160	157	157	± 0	158	166	164	+ 2	163	[161]	167	[− 6]	166	150	148	+ 2	148	154	154	± 0	154
9. Dog Rose	167	165	+ 2	165	160	166	− 6	166	164	167	− 3	168	171	169	+ 2	169	177	169	+ 8	167	159	159	± 0	159	163	163	± 0	163
10. Black Knapweed	199	198	+ 1	198	[196]	199	[− 3]	199	187	192	− 5	193	200	198	+ 2	197	[203]	204	[− 1]	203	180	180	± 0	180	188	190	− 2	190
11. Harebell	192	196	− 4	194	(193)	194	(− 1)	193	190	191	− 1	191	197	195	+ 2	195	[195]	197	[− 2]	197	191	189	+ 2	189	193	192	+ 1	192
12. Greater Bindweed	201	203	− 2	204	(191)	198	(− 7)	198	197	198	− 1	199	218	207	+11	206	[269]	202	[+ 7]	200	190	191	− 1	191	197	198	− 1	198
13. Ivy	277	277	± 0	276	[275]	277	[− 2]	277	286	280	+ 6	280	(286)	290	(− 4)	289	[285]	291	[− 6]	290	271	270	+ 1	270	274	276	− 2	276
14. Devil's-Bit Scabious	211	...	...	...	(227)	...	...	...	217	...	...	...	215	...	...	...	[226]	...	...	...	219	...	...	...	219	...	...	...
Mean of Plants 1-13	144	144	± 0	144	143	149	− 6	149	144	146	− 2	146	156	153	+ 3	153	153	154	− 1	153	138	138	± 0	139	142½	143½	− 1	143½
Mean of Plants 1-14	149	...	...	...	149	...	...	...	149	...	...	...	166	...	...	...	158	...	...	...	144	...	...	...	148	...	...	...

* Average of Districts A, C, D, E, F, I. + Signifies that the date of flowering is late; − that it is early. † The mean of the 13 plants for the British Isles

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TABLE V.—Mean Dates of Flowering, with their Variations from the 35 Years' Average (1891-1925), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made. Also, Total Number of Stations in all Eleven Districts.

Years.	No. of Stations.	A (8), Eng. S.W.		C (5), Eng. S.E.		D (4), Eng. Mid.		E (3), Eng. E.		F (7), Eng. N.W.		Mean Variation from Average for the 5 Districts.
		Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	
			Days.		Days.		Days.		Days.		Days.	Days.
1891	105	144	+10	144	+ 9	150	+11	147	+11	150	+ 7	+ 9.6
1892†	107	139	+ 5	138	+ 3	144	+ 5	143	+ 7	147	+ 4	+ 4.8
1893	117	118	−16	122	−13	125	−14	123	−13	128	−15	−14.2
1894	113	126	− 8	130	− 5	135	− 4	127	− 9	137	− 6	− 6.4
1895	118	139	+ 5	138	+ 3	141	+ 2	138	+ 2	144	+ 1	+ 2.6
1896†	115	125	− 9	128	− 7	132	− 7	130	− 6	134	− 9	− 7.6
1897	110	130	− 4	132	− 3	136	− 3	132	− 4	142	− 1	− 3.0
1898	127	133	− 1	135	0	138	− 1	136	0	141	− 2	− 0.8
1899	116	136	+ 2	136	+ 1	141	+ 2	138	+ 2	145	+ 2	+ 1.8
1900	119	142	+ 8	141	+ 6	144	+ 5	143	+ 7	152	+ 9	+ 7.0
1901	125	138	+ 4	139	+ 4	141	+ 2	139	+ 3	144	+ 1	+ 2.8
1902	124	139	+ 5	140	+ 5	143	+ 6	142	+ 6	152	+ 9	+ 6.2
1903	118	134	0	134	− 1	137	− 2	134	− 2	145	+ 2	− 0.6
1904†	115	139	+ 5	139	+ 4	142	+ 3	140	+ 4	149	+ 6	+ 4.4
1905	117	133	− 1	135	0	138	− 1	136	0	144	+ 1	− 0.2
1906	108	135	+ 1	134	− 1	138	− 1	137	+ 1	143	0	0
1907	109	142	+ 8	139	+ 4	143	+ 4	142	+ 6	149	+ 6	+ 5.6
1908†	116	139	+ 5	138	+ 3	142	+ 3	142	+ 6	148	+ 5	+ 4.4
1909	109	140	+ 6	140	+ 5	144	+ 5	142	+ 6	150	+ 7	+ 5.8
1910	107	136	+ 2	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.6
1911	104	135	+ 1	133	− 2	137	− 2	134	− 2	133	−10	− 3.0
1912†	107	127	− 7	128	− 7	132	− 7	130	− 6	137	− 6	− 6.6
1913	125	125	− 9	126	− 9	134	− 5	130	− 6	142	− 1	− 6.0
1914	132	126	− 8	128	− 7	133	− 6	129	− 7	135	− 8	− 7.2
1915	127	133	− 1	134	− 1	139	0	137	+ 1	142	− 1	− 0.4
1916†	117	132	− 2	132	− 3	141	+ 2	140	+ 4	142	− 1	0
1917	114	141	+ 8	141	+ 6	149	+10	145	+ 9	148	+ 5	+ 7.6
1918	110	131	− 3	131	− 4	134	− 5	134	− 2	135	− 8	− 4.4
1919	103	134	0	134	− 1	141	+ 2	140	+ 4	141	− 2	+ 0.6
1920†	212	126	− 8	123	−12	131	− 8	129	− 7	137	− 6	− 8.2
1921	205	125	− 9	120	−15	127	−12	125	−11	133	−10	−11.4
1922	239	137	+ 3	136	+ 1	140	+ 1	138	+ 2	145	+ 2	+ 1.8
1923	357	129	− 5	130	− 5	136	− 3	131	− 5	145	+ 2	− 3.2
1924†	365	139	+ 5	138	+ 3	144	+ 5	141	+ 5	149	+ 6	+ 4.8
1925	362	136	+ 2	134	− 1	138	− 1	135	− 1	143	0	− 0.2
Average 1891-1925	...	134	...	135	...	139	...	136	...	143	...	[137.4]
		My. 14		My. 15		My. 19		My. 16		My. 23		[My17]

† Leap years.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925.

Song-Thrush (*Turdus musicus*) first heard; Swallow (*Hirundo rustica*) first seen; Cuckoo (*Cuculus canorus*) first heard; Nightingale (*Daulias luscinia*) first heard; Flycatcher (*Muscicapa grisola*) first seen; Swallow (*Hirundo rustica*) last seen; Honey-Bee (*Apis mellifica*); Wasp (*Vespa vulgaris*); Small White Butterfly (*Pieris rapæ*); Orange-Tip Butterfly (*Anthocaris cardamines*); Meadow-Brown Butterfly (*Epinephile janira*); Humble Bee (*Bombus lapidarius*) first seen.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
Channel Isles: Guernsey.												
A.												
0a. Les Blanches	1	88	108	...	...	298	...	...	109	...	166	*127*
0d. Les Hubits	3	109	109	112	...	305	...	...	98	...	173	...
A (8)												
1a. Carbis Bay	2	102	108	...	...	290	78	...	88	...	...	...
1b. St. Buryan	2	109	107	...	*153*	307	...	...	...	150	...	...
2c. Mawgan	16	103	111	...	128	308	*103*	18	104	108	159	77
2d. Mawnan	1	110	120	...	...	284	...	...	101	163	141	75
2e. Devoran	1	115	109	...	...	...	...	...	102	...	...	...
* Polperro	1	103	96	...	...	285	73	...	...	136	166	95
6a. Duloe	9	97	110	...	*165*	285	17	...	...	93	*102*	...
9a. Launceston	15	109	112	...	...	...	65	...	106	...	...	...
6c. Lopwell	...	108	98	...	130	275	53	95	102	117	165	...
9c. Clawton	2	110	122	...	139	...	92	...	106	...	...	...
10b. Torquay	5	132	109	...	...	282	5	132	95	...	...	...
11c. Spreyton	...	...	109	...	...	...	78	94	102	134	136	99
11d. Copplestone	1	99	112	...	...	...	34	...	*132*	...	...	...
11e. Bridestowe	10	117	109	...	145	276	...	98	118	134	...	...
12c. Bradworthy	...	102	112	...	...	284	...	...	110	*49*	...	95
13a. Exmouth	11	107	109	...	139	265	64	137	91	...	185	74
13c. Exeter	1	97	109	...	146	254	...	...	102	...	...	...
14b. Bish'p's Tawton	3	106	109	...	...	264	...	93	115	148	...	...
15a. Buckerell	14	103	103	...	109	...	...	...	103	132	...	97
15b. Colyford	...	106	109	...	...	...	97	...	97	142	155	...
† Combe Martin	1	93	97	...	...	...	15	...	91	156	173	51
17e. Ilfracombe	42	*158*	120	...	144	...	57	...	115	152	...	...
15c. Lyme Regis	1	...	...	125	...	256	23	...	91	162	161	36
21c. Sturminster Marshall	17	99	105	117	130	...	...	...	...	...	...	...
21d. Broadstone	2	89	100	118	144	277	...	...	110	144	140	...
22a. Pulham	3	113	101	121	149	283	101	...	...	163	...	...
24a. Blandford	3	*78*	*78*	110	130	274	35	...	...	...	...	77
24d. West Melbury	20	101	109	...	*178*	265	...	137	130	135	182	100
19c. Bradney	1	104	115	114	...	...	...	...	101	...	...	...
19f. Taunton	2	112	111	114	*113*	...	100	...	98	...	...	95
19g. West Buckland	3	108	109	115	...	...	95	137	...	...	...	60
20a. West Porlock	1	93	109	118	145	...	...	...	...	...	...	...
22c. Street	1	98	107	114	...	276	...	82	...	...	...	...
22d. Bruton	6	93	108	115	*113*	...	84	...	...	...	...	59
25b. Flax Bourton	6	102	111	117	140	293	18	101	98	132	143	*143*
25c. Keynsham	1	110	111	...	130	259	69	98	111	141	163	98

* Combination of 3 stations, 5a, b, c. † Combination of 3 stations 17a, b, d.
The dates in *italics* in Table VI. represent rejected values, and have not been taken into consideration when calculating the means for the Districts.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
27c. Portishead	2	102	108	127	...	278	63	127	101	100	165	98
28b. Clevedon	3	102	112	...	141	266	...	...	111	161	163	*144*
28d. Llandaff	2	93	109	...	130	276	...	...	...	...	...	...
29a. Bridgend	1	108	123	...	...	...	...	135	119	...	...	93
30a. Mumbles	2	113	109	...	136	296	32	132	98	134	165	...
32a/b. Tenby	11	109	117	...	...	277	...	...	91	...	...	98
33a. St. Davids	14	110	118	...	...	...	87	...	110	159	173	...
35a. Fishguard	44	93	116	...	...	...	8	...	100	...	...	60
34c. Philadelphia	18	101	110	...	...	289	...	...	...	99	...	93
36a. Llandilo	5	94	118	...	135	...	...	...	...	...	...	...
43a. Hafod	3	121	120	...	...	...	77	135	134	136	170	...
43c. Aberystwyth	10	108	110	...	137	275	...	121	97	130	159	77
B (10).												
6a. Timoleague	4	100	121	...	142	...	...	*158*	91	122	175	128
14a. Monkstown	2	100	...	...	...	290	...	...	...	...	...	...
14b. Passage West	7	113	128	...	...	*243*	...	...	116	*158*	172	...
22b. Castle Lyons	4	110	110	...	143	269	65	79	110	118	172	126
27a. Castleconnell	10	102	128	...	140	...	...	...	...	...	...	...
30a. Cashel	10	105	120	...	*174*	258	110	*157*	126	...	170	93
34b. Kilkenny	...	110	113	...	...	269	30	*134*	...	...	...	86
34d. Freshford	...	107	128	...	...	282	98	...	111	132	...	...
42a. Ballickmoyler	...	102	123	...	142	...	100	...	120	143	...	96
41a. Ferns	2	111	110	...	132	303	60	102	100	132	171	*144*
43a. Mountmellick	1	99	121	...	149	269	76	9	110	137	169	...
43b. Stradbally	32	109	110	...	...	277	...	– *29*	...	129	...	...
49b. Dundrum	12	114	*141*	...	...	282	...	...	...	...	...	82
50a. Johnstown Bridge	...	114	124	...	...	275	76	...	110	148	...	76
C (5).												
4c. Salisbury	1	90	109	...	96	289	77	*139*	93	...	...	...
5b. Holt	23	100	107	...	...	277	53	...	...	...	...	...
5c. Bratton	1	110	112	120	132	286	...	...	...	...	...	...
8b. Marlborough	27	102	119	*148*	136	288	77	62	130	136	164	*131*
1a/e. Bournemouth	3	102	118	...	...	276	67	67	...	...	...	...
1f. Boscombe	*48*	116	124	...	...	282	*117*	102	*132*	...	...	79
1b. Ringwood	1	106	109	113	...	279	59	...	77	133	...	...
1c. Lymington	1	108	108	119	153	313	60	111	84	133	...	101
1i. Appleslade, Ringwood	5	92	107	...	140	277	93	...	92	...	162	74
1d. Totland Bay	...	108	112	...	...	315	...	...	...	...	...	...
3a. Shanklin	4	96	110	115	124	305	...	84	100	132	154	100
3b. Newport	8	90	*85*	120	...	310	18	112	84	140	167	80
3e/f. Southsea	9	96	96	112	120	283	51	93	98	116	150	100
4b. Sherfield English	1	96	97	110	*164*	281	38	*152*	98	143	156	101
4d. Lyndhurst	...	103	109	119	...	273	...	...	...	...	...	...
6a. Havant	1	107	107	116	...	291	...	...	...	133	169	80
6d. Hayling Island	1	116	112	120	...	300	9	131	101	135	159	80

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly	Meadow-Brown Butterfly.	Humble Bee
7a. Botley	1	97	96	114	130	308	35	...	98	135	176	97
7b. West Meon	5	110	109	113	...	272	59	*137*	101	136	*100*	...
7c. Hythe, S'hampton	1	100	107	113	131	308	58	67	115	119	*117*	75
7f. Sutton Scotney	1	106	109	118	152	...	...	104	102	...	...	60
7h. Winchester	1	99	112	...	...	282	22	...	...	...	...	...
11b. Newton Valence, Alton	3	111	108	118	133	...	35	...	...	...	...	98
15k. Yateley	...	124	108	126	145	...	...	...	...	...	...	...
17c. Bradfield	6	116	100	*97*	...	...	...	35	...	...	...	...
20a. Reading	4	108	103	119	...	293	59	...	98	140	166	100
20c. Maidenhead	...	109	109	124	155	...	...	...	...	...	...	...
6c. Chichester	1	98	109	123	...	304	77	99	98	134	171	77
10a. Littlehampton	47	115	115	...	...	...	*114*	...	102	102	*112*	83
10b. Hove	5	118	115	...	140	279	74	119	110	132	145	85
10d. Portslade	1	100	108	105	128	293	62	78	106	133	154	73
15b/d. Horsham	1	104	107	111	116	273	35	93	95	113	153	114
15c. Steyning	...	...	...	...	...	...	...	...	115	118	160	74
18a. Lewes	1	100	109	114	130	312	67	135	101	133	164	116
18b. Hellingly	5	105	109	115	...	298	6	32	115	144	145	...
18c. Ditchling	2	100	110	*97*	121	295	43	12	86	116	177	67
21a. Brede	5	116	103	116	133	...	84	*137*	116	135	161	68
21b. Hastings	...	106	107	108	...	...	...	...	...	...	...	...
16b. Farnham	5	114	111	130	...	260	...	...	...	92	...	...
16g. Rowledge	1	113	108	115	135	...	66	*151*	129	...	...	*150*
16i. Churt	5	127	110	135	...	...	46	...	*133*	133	162	*137*
19a. Cranleigh	2	...	96	132	140	...	...	...	...	...	...	...
22a. Lingfield	3	109	108	135	137	273	75	*149*	119	137	180	69
22b. Warlingham	1	...	109	114	...	...	35	31	103	136	...	100
22c. Purley	1	112	98	120	...	276	94	126	122	136	180	101
22e. Limpsfield	...	121	108	116	...	...	...	...	...	...	...	...
24a. Lympne	1	112	112	116	...	...	...	...	116	...	...	...
24b. Woodchurch	5	108	97	112	...	315	...	...	*133*	119	...	100
25a/c Maidstone	10	112	100	102	...	...	...	...	101	137	...	...
25b. Mereworth	15	112	107	115	121	...	91	116	112	137	166	99
26a/c. Bromley	20	110	109	114	...	...	76	59	129	...	...	...
28a. Rochester	1	109	122	123	151	283	95	...	102	126	...	100
D (4)												
1b. Wotton-under-Edge	...	...	111	...	...	307	...	136	...	136	...	135
5b/c. Cheltenham	4	109	111	...	...	...	102	93	101	148	167	75
5d. Coaley	5	98	108	*141*	138	282	89	60	*154*	128	168	84
6a. Dymock	1	108	107	...	141	277	39	101	97	134	...	*142*
3b. Ross	5	117	115	...	144	...	74	...	102	...	...	...
4a. Weobley	...	...	109	...	...	274	66	...	116	154	...	111
4b. Staunton-on-Arrow	1	107	107	...	134	283	75	74	101	133	172	110
6b. Bromyard	9	121	111	...	...	291	...	...	...	...	...	...
6c. Kimbolton, Leominster	11	111	109	...	...	...	*133*	...	118	134	177	...

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
11b/c.	Ludlow	36	118	110	...	...	...	99	...	136	136	149	...
17a.	Edgmond	1	108	115	...	...	277	70	115	...	...	...	...
10b.	Evesham	3	112	...	125	...	278	...	...	...	...	...	...
11a.	Tenbury	1	100	108	128	135	276	72	102	102	131	165	119
16b.	Wolverley, Cookley	1	111	113	133	142	271	...	...	98	...	...	89
16c.	Barnt Green	2	101	111	...	136	...	36	119	...	...	...	...
10c.	Ashorne	14	110	111	...	...	285	...	99	111	153	...	...
15a.	Whernalls	...	108	110	113	133	...	...	...	...	...	...	...
15c.	Stratford-on-Avon	5	111	109	115	141	269	94	144	100	136	161	101
16d.	Quinton	19	110	119	...	...	270	59	130	132	135	146	107
16e.	South Birmingham	8	98	108	...	129	274	...	...	132	144	175	...
20a.	Farnborough	3	105	114	...	128	269	72	98	115	144	180	*153*
21b.	Erdington	4	115	114	...	...	...	102	...	107	...	...	...
21d.	Hampton-on-the-Hill	3	113	108	122	...	...	74	...	...	...	...	...
21e.	Leamington Spa	3	108	116	...	...	...	...	...	...	140	...	...
21f.	Hall Green	3	102	122	...	...	258	...	...	...	...	...	...
21g.	King's Heath	...	109	118	...	...	...	101	101	*157*	...	179	...
26b.	Sutton Coldfield	1	108	113	...	142	296	110	...	...	...	...	...
14a/b	Oxford	11	103	108	122	...	276	90	...	102	...	...	98
19a.	Weston Turville	...	115	109	...	...	269	...	...	...	...	158	...
19b.	Granborough	1	109	113	...	127	274	74	97	101	133	...	93
24a.	Bletchley	9	114	114	*141*	...	273	63	104	112	135	...	117
24b.	Northampton	1	110	112	134	...	274	75	...	102	...	...	...
33a.	Ketton	*79*	112	120	121	137	...	72	...	99	132	...	...
25a.	Mowsley	5	101	117	...	135	...	...	...	...	...	...	...
34a.	Kegworth	3	113	112	...	...	295	74	92	101	153	156	103
35a.	Somersal Herbert	11	101	120	...	125	...	*146*	64	102	131	180	...
35b.	Matlock.	16	110	121	...	125	269	...	...	...	...	...	...
37b.	Balderton	18	112	*136*	...	...	...	...	...	...	136	168	101
38a.	Hodsock	8	106	110	...	135	276	51	123	133	...	190	...
39a.	Huddersfield	6	132	118	...	...	...	67	138	137	...	...	131
39b.	Kirkheaton	55	96	96	...	...	260	*134*	...	136	...	...	...
39c.	Thurlstone	10	120	121	...	...	270	86	*145*	121	*166*	...	*169*
41c.	Grindleton	19	119	129	...	124	...	...	*144*	...	...	...	*146*
41d.	Crosshills	17	100	117	...	...	286	72	...	130	...	...	99
44a.	Sitwell Vale	12	130	...	...	...	272	104	...	134	...	...	...
44b.	Newhill, Wath	11	110	123	...	...	274	...	136	133	...	...	...
45a.	Middlestown	15	118	113	...	...	270	101	136	136	...	...	...
45b.	Altofts	25	120	117	...	...	...	...	...	...	...	...	...
49b.	Fairburn	17	110	123	...	...	294	...	...	133	...	...	...
	E (3)												
1c.	Barnet	7	99	109	...	123	282	100	...	100	136	...	101
1d.	Whetstone	16	109	111	...	132	...	48	102	102	...	...	114
2a.	Berkhamsted	6	104	112	*142*	*181*	...	72	126	102	*168*	136	135

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
2b.	Tring	48	100	100	119	...	313	...	...	111	131	...	...
4b.	Knebworth	14	97	107	109	...	...	30	...	...	...	...	100
4c/l	Harpenden	5	108	109	123	134	273	39	...	...	135	181	133
4i.	Hitchin	2	99	97	100	132	305	23	...	102	...	169	99
4k.	Pirton, Hitchin	27	102	111	...	...	274	99	137	127	137	171	107
7b.	Sawbridgworth	1	99	108	121	130	309	23	133	119	133	163	95
7f.	Buntingford	8	107	100	...	*96*	282	64	98	109	138	104	111
*	Letchworth	1	99	94	100	...	290	17	54	101	119	136	101
5a.	Turvey	3	100	113	118	140	291	46	130	101	132	155	101
8a.	Kempston	1	110	115	...	132	275	68	...	101	109	...	...
10a.	Maldon	6	109	116	111	...	274	102	*146*	99	138	171	102
10b.	Halstead	6	111	112	...	...	283	60	...	103	132	165	...
10d.	Tolleshunt Knights	13	109	114	115	...	285	...	...	...	...	...	...
10f.	Great Totham	20	109	110	117	...	288	34	93	119	115	77	84
13a.	Lexden	14	103	109	116	139	297	75	98	...	134	174	...
13b.	Colchester	...	102	117	121	...	...	...	129	103	133	...	...
11d.	Cambridge	1	108	113	115	129	273	*135*	...	...	131	...	*143*
14a.	Ballingdon	3	111	113	113	135	291	79	98	111	137	164	77
17a.	Belstead, Ipswich	11	102	105	115	125	...	...	...	...	...	...	...
17c.	Ipswich	...	107	122	122	129	...	...	...	...	...	...	...
17d.	Bramford, Ipswich	...	107	113	122	...	...	...	...	110	...	...	...
23a.	Bungay	5	115	130	...	...	274	80	92	112	140	148	92
22b.	Langford	3	100	110	115	...	278	60	132	112	132	165	98
24b.	Postwick	1	*136*	102	...	...	248	88	115	94	...	...	83
25a.	Hunstanton	9	98	111	...	128	273	...	...	113	151	...	95
	F (7)												
9a.	Beaumaris	3	104	125	...	142	264	97	128	125	163	...	*164*
9b.	Deganwy	4	108	114	...	*150*	269	...	...	...	...	...	74
10a.	Wrexham	16	115	120	...	142	...	...	...	...	...	...	...
11d.	Trefnant	2	108	121	...	...	...	97	98	102	...	...	...
13c.	Higher Tranmere	7	117	123	...	...	...	...	137	111	...	...	96
13d.	Shotwick	15	109	110	...	122	283	98	135	134	136	161	*134*
14a.	Barnton	3	101	110	...	...	275	71	100	122	132	*196*	97
14b.	Altrincham	1	114	115	...	132	263	*130*	135	136	...	...	...
16a.	Prestbury	...	111	124	...	...	270	99	96	137	...	...	109
16b.	Bramhall	21	106	116	...	140	278	37	103	107	...	171	102
18a.	Blackpool	24	*138*	124	...	138	*261*	...	...	118	...	166	132
19a.	Stockport	20	108	114	...	...	279	117	113	121	139	143	92
21a.	Leyland	3	110	129	...	...	258	...	...	...	...	172	...
21b.	Ashton-on-Ribble	10	120	120	...	...	...	102	*158*	123	152	*136*	100
22a.	Urswick	*59*	103	114	...	...	274	97	*155*	97	157	184	*174*
22b.	Ulverston	3	113	126	...	131	298	...	...	...	...	...	...

* Combination of 3 stations 8a, b, c.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
22d.	Grange over-Sands	...	...	...	...	...	...	...	...	92	134	165	...
25a.	Ambleside	15	100	119	...	140	284	63	...	136	146	...	...
28b.	Johnby Hall	49	135	142	...	...	261	130	137	*155*	...	...	...
28c.	Mungrisdale	20	116	119	...	132	264	...	...	...	...	...	102
31a.	Kelsick	3	111	122	...	...	254	...	101	110	137	175	133
32a.	Alston	...	110	121	...	127	291	...	...	...	182	...	...
	G (9)												
18 a.	Longford	12	114	115	...	...	302	101	121	114	130	157	...
41a.	Bessbrook	10	110	122	...	137	302	79	115	115	137	189	...
41c.	Scarva	12	107	*148*	...	...	...	111	...	113	121	...	120
35c.	Warrenpoint	7	97	122	...	125	295	...	121	98	129	157	77
35d.	Rostrevor	9	109	118	...	...	273	110	104	110	137	175	*134*
50a.	Hillsborough	4	109	110	...	155	276	...	104	143	155	...	...
47a.	Sixtowns	11	110	121	...	...	271	...	...	...	137	184	...
51a.	Magherafelt	1	111	121	...	...	255	112	117	149	149	152	*152*
48b.	Milford	*50*	109	115	...	...	...	98	...	130	...	...	110
50c.	Belfast	11	*70*	120	...	...	277	...	...	...	...	...	...
50d.	Muckamore	7	114	128	...	...	270	.	...	...	...	...	...
50f.	Woodburn	24	112	109	...	...	*246*	...	*169*	*154*	...	*116*	109
54a.	Hazelbank	5	98	112	...	...	284	60	103	103	137	153	100
55a.	Ballymoney	3	109	119	...	...	265	104	...	130	130	...	*140*
	H Isle of Man:												
6a.	Douglas*	35	99	...	...	142	*315*	...	...	...	...	...	...
	H (6).												
1a.	Kirkmaiden	18	110	122	...	...	271	60	123	117	122	147	103
2a.	Marks	15	109	121	...	...	...	96	96	119	...	...	...
27b.	Larkhall	17	118	102	...	...	271	74	65	130	...	...	74
33a.	Ledaig, Oban	16	120	121	...	...	...	*135*	119	136	...	...	...
	I (2).												
5b.	Kirton, Boston	9	111	114	...	138	270	102	82	102	151	...	*131*
8a.	Woodhall Spa	...	111	120	120	...	...	...	...	...	146	...	...
9a.	Ashby	13	110	117	...	...	...	62	...	111	...	...	...
10a.	West Keal	17	121	110	...	142	264	35	*134*	...	138	...	*153*
11b.	ThorntonAbbey	8	101	116	...	...	291	...	...	...	163	...	104
11d.	Cleethorpes	16	104	106	...	...	...	108	123	117	...	...	...
20a.	Louth	18	116	110	...	...	...	...	100	102	...	179	102
12a.	Howdenshire	10	102	115	...	145	...	...	...	...	...	...	...
16a.	Whitaside	35	132	124	...	...	...	...	130	...	...	...	*136*
18a.	Middleton-in-Teesdale	38	96	116	...	...	287	38	133	131	...	*129*	...
21a.	Hull	3	120	126	...	...	302	101	118	110	140	160	94
23a.	Thirsk	10	96	122	...	140	275	73	113	132	160	...	...
27a.	Withernsea	15	105	97	...	...	268	*140*	..	*187*	*171*	...	104
24b.	Darlington	18	103	121	...	...	270	...	9	130	143	167	...
33a.	Lanchester	25	112	116	...	...	268	100	2	101	...	...	114

* Not included in the means for District H.

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TABLE VI.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1925—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
33b. Chopwell	34	113	122	...	*122*	285	87	74	115	...	173	85
33c. Chester-le-Street	...	133	135	...	...	...	...	133	135	...	...	118
33f. North Shields*	...	136	129	...	...	277	...	...	...	...	...	...
19a. Haltwhistle	24	102	122	...	130	289	...	...	...	...	...	...
25a/c Corbridge	12	111	123	...	...	...	74	...	146	...	...	...
25b. Stocksfield	...	116	129	...	...	263	...	...	139	...	...	109
25d. Allendale	42	111	124	...	...	...	...	129	136	...	...	99
26a. Catcleugh	17	111	122	...	140	275	...	132	128	...	...	...
36a. Seaton Delaval	17	127	124	...	...	...	...	...	124	...	...	...
38a. Embleton	17	...	...	...	134	262	102	92	...	...	...	...
38b. Belford	21	111	123	...	*165*	282	100	*162*	...	134	...	81
38c. Lemmington	12	107	124	...	153	283	109	117	110	117	169	*63*
39a. Berwick	5	115	135	...	...	268	100	*146*	146	...	...	*139*
J (1).												
6b. Jedburgh	11	112	136	...	...	272	102	133	...	...	...	125
4a. Selkirk	12	109	122	...	144	275	...	...	...	...	...	...
6a. Galashiels	17	113	122	...	...	264	52	*161*	...	...	...	97
2a. Broughton	16	116	121	...	133	278	74	101	139	...	...	...
10a. West Foulden	11	109	114	...	...	283	...	111	137	...	180	...
13a. Stirling	10	111	120	...	141	257	50	139	...	...	...	85
20a. TummelBridge	27†	...	124	...	139	269	...	...	...	...	...	...
35b. South Fowlis	...	125	122	...	127	255	*11*	*147*	139	...	...	130
36a. Cabrach	65	120	122	...	...	263	100	129	154	163	181	126
39a. Dunlugas	61	129	121	...	124	273	76	128	153	169	179	95
39b. Forglen	47	124	126	...	136	...	65	138	...	...	...	112
40b. Kellas	...	119	116	...	...	...	...	134	128	...	...	...
K (0).												
27b. Kirkhill	47	127	125	...	...	266	*140*	142	150	...	156	101
24b. Muir of Ord	28	132	125	...	...	...	63	...	...	...	...	108
33a. Golspie	20	123	125	...	...	...	...	...	...	...	...	101
Total Records Used	271	359	366	103	120	201	172	138	209	150	112	137

* Received too late for inclusion in means. † Observed at Aberfeldy, 10 miles S.

(*Continued from page* 297.)

Second Flowering was also less noted. A6a, field rose, *R. arvensis,* in Nov.; elsewhere, fruit trees in Oct., result of June drought; so lilac, black currant, laburnum, holly. At B50a, "some apples kept on all the year."

Fruiting. Tree fruits failed as a rule in part or whole; berries did better, unaffected by earlier drought. Acorn and mast fared badly and hazel nuts as a rule. All report pear failure; A9b, "worst ever known"; plums little better; apples coloured well but were bad keepers, often

(*Continued on page* 314.)

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TABLE VIA. MEAN DATES (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS IN 1925, AND DIFFERENCE FROM THE AVERAGE OF THE 35 YEARS, 1891–1925.

BIRDS AND INSECTS.	Channel Islands 1925.	A (8) England, S.W.				B (10) Ireland, S.				C (5) England, S.E.				D (4) England, Mid.				E (3) England, E.				F (7) England, N.W.			
		1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.
1. Song Thrush First Heard	2	7	15	− 8	16	9	12	− 3	13	6	14	− 8	15	9	19	−10	20	9	16	− 7	16	12	24	− 12	26
2. Swallow First Seen	(99)	105	105	0	105	106	105	+ 1	104	106	105	+ 1	106	109	109	0	109	104	109	− 5	109	110	110	0	110
3. Cuckoo First Heard	109	110	111	− 1	111	120	116	+ 4	115	100	107	+ 2	107	113	112	+ 1	112	110	111	− 1	111	120	117	+ 3	117
4. Nightingale First Heard	[112]	117	120	− 3	120	...	...	...	...	117	112	+ 5	111	123	117	+ 6	116	114	114	0	113	...	122	...	122
5. Spotted Flycatcher First Seen	...	137	134	+ 3	134	141	135	+ 6	135	133	132	+ 1	132	134	135	− 1	136	131	135	− 4	136	135	131	+ 4	131
6. Swallow Last Seen	(301)	279	282	− 3	283	275	279	− 4	281	280	292	− 3	292	277	282	− 5	283	284	289	− 5	291	273	279	− 6	279
Mean of Nos. 2, 3 and 5	...	117	117	0	117	122	119	+ 3	118	116	115	+ 1	115	119	119	0	119	115	118	− 3	119	122	119	+ 3	119
7. Honey Bee at Flowers	...	58	58	0	58	77	61	+16	58	60	56	+ 4	55	79	59	+20	56	58	53	+ 5	52	92	65	+ 27	62
8. Queen Wasp on Wing	...	110	96	+14	95	63	99	−36	94	94	94	0	94	105	101	+ 4	101	103	94	+ 9	94	117	105	+ 12	104
9. Small White Butterfly	(103)	106	102	+ 4	102	110	108	+ 2	107	105	103	+ 2	103	116	112	+ 4	111	107	107	0	107	115	114	+ 1	112
10. Orange-Tip Butterfly	...	139	127	+12	127	133	121	+12	120	130	127	+ 3	128	138	133	+ 5	133	133	132	+ 1	133	147	136	+ 11	135
11. Meadow Brown Butterfly	(169)	161	160	+ 1	161	171	146	+25	146	162	164	− 2	165	168	167	+ 1	167	150	167	−17	167	167	170	− 3	170
12. Humble Bee	...	81	...	...	...	98	...	...	...	87	...	...	...	104	...	...	...	102	...	...	...	104	...	...	...
Mean of Nos. 7-11	...	115	109	+ 6	109	111	107	+ 4	106	110	109	+ 1	109	121	114	+ 7	114	110	111	− 1	111	128	118	+ 10	117

BIRDS AND INSECTS.	G (9) Ireland, N.				H (6) Scotland, W.				I (2) England, N.E.				J (1) Scotland, E.				K (0) Scotland, N.				England and Wales.*				British Isles.†			
	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.	1925.	Average 35 years.	Difference from 35-year Average.	Average 30 years.
1. Song Thrush	9	20	− 11	22	17	29	−12	31	19	30	−11	31	27	28	− 1	28	35	41	− 6	42	10	19	− 9	21	14	23	− 9	24
2. Swallow First Seen	110	108	+ 2	108	115	113	+ 2	114	112	114	− 2	114	115	118	− 3	118	125	126	− 1	126	108	109	− 1	109	111	111	0	111
3. Cuckoo	120	118	+ 2	119	117	120	− 3	120	119	119	0	119	123	123	0	124	126	125	+ 1	126	113	113	0	113	117	116	+ 1	117
4. Nightingale	...	129	...	129	...	...	...	...	[120]	120	[0]	116	...	...	...	...	...	...	...	...	118	117	+ 1	116	‡124	‡125	− 1	‡124
5. Spotted Flycatcher	139	137	+ 2	137	...	140	...	137	140	135	+ 5	135	135	139	− 4	139	...	158	...	159	135	134	+ 1	134	136	137	− 1	137
6. Swallow Last Seen	279	275	+ 4	275	(271)	275	(−4)	277	277	279	− 2	280	269	270	− 1	270	[266]	260	[+6]	261	280	284	− 4	285	276	278	− 2	279
Mean of Nos. 2, 3 and 5	123	121	+ 2	121	...	124	...	124	124	123	+ 1	123	124	127	− 3	127	...	136	...	137	119	119	0	119	121	121	0	122
7. Honey Bee	93	73	+ 20	71	73	72	+ 1	71	85	64	+21	61	74	68	+ 6	69	[63]	66	[−3]	63	72	59	+13	57	74	63	+ 11	61
8. Queen Wasp	112	109	+ 3	108	104	121	−17	122	112	111	+ 1	111	124	117	+ 7	118	[142]	120	[+22]	122	107	100	+ 7	100	108	106	+ 2	106
9. Small White Butterfly	121	115	+ 6	115	123	124	− 1	123	124	119	+ 5	119	140	129	+11	129	[150]	134	[+16]	136	112	109	+ 3	109	120	115	+ 5	115
10. Orange-Tip Butterfly	139	130	+ 9	129	[122]	131	[−9]	136	144	143	+ 1	143	156	151	+ 5	151	...	*148*	...	*148*	139	133	+ 6	133	138	135	+ 3	135
11. Meadow Brown B'fly	167	165	+ 2	166	[147]	167	[−20]	171	170	167	+ 3	168	180	175	+ 5	174	[156]	*172*	[−16]	*172*	163	167	− 4	167	164	165	− 1	166
12. Humble Bee	103	...	...	...	89	...	...	...	101	...	...	...	109	...	...	...	106	...	...	...	97	...	...	...	99	...	...	...
Mean of Nos. 7-11	126	118	+ 8	118	114	123	− 9	125	127	121	+ 6	120	135	128	+ 7	128	...	128	...	128	119	114	+ 5	113	120	117	+ 3	117

* Average of districts A, C, D, E, F, I. † The British Isles means in both Tables (VIA and VII) are the means of the separate districts. ‡ The difference between the dates for the Nightingale and the Cuckoo in those districts in which *both* have been recorded, has been used as a basis for deriving the British Isles means for Nightingale. ( ) Show means of two observations only. [ ] One observation only. Values in *italics* have been interpolated owing to lack of data and are approximate only.

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TABLE VII.—ARRIVAL OF

STATIONS. (131 selected out of about 300 of our observers, besides over 100 from periodicals.)	Mean Value.*	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Wryneck (*Iynx torquilla*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucus*).	Yellow Wagtail (*Motacilla Rayi*).	Redstart (*Ruticilla phœnicurus*).	House Martin (*Chelidon urbica*).
		1	2	3	4	6	7	8	10	11	12	13
A of† Guernsey	117.7	82	111	103	111	*111*	*109*	*118*	*114*	*115*	*118*	129
2c. Mawgan	116.8	95	*89*	*120*	*104*	*111*	*109*	*118*	*114*	*115*	*118*	*116*
6c. Lopwell	113.9	95	88	95	102	*111*	*109*	95	*114*	*115*	*118*	109
11e. Bridestowe	118.7	98	93	*120*	101	*111*	*109*	134	118	*115*	*118*	119
12c. Bradwothy	117.5	96	84	*120*	109	110	*109*	*118*	*114*	*115*	*118*	110
13c. Exeter	117.8	100	*89*	*120*	100	117	*109*	120	*114*	*115*	*118*	121
14a. Umberleigh	117.0	96	*89*	*120*	95	93	*109*	*118*	98	*115*	*118*	109
15b. Colyford	117.1	99	*89*	*120*	100	101	*109*	*118*	107	*115*	*118*	124
17‡ Combe Martin	118.0	95	*89*	*120*	101	*111*	*109*	130	*114*	*115*	*118*	107
21c. Sturminster Marshall	115.3	96	79	*120*	97	120	*109*	*118*	*114*	*115*	*118*	120
24a. Blandford	114.4	96	65	*120*	*104*	*111*	*109*	115	*114*	*115*	*118*	116
24d. West Melbury	118.1	100	*89*	*120*	100	*111*	100	123	*114*	*115*	*118*	102
19g. West Buckland	116.1	95	*89*	*120*	102	*111*	*109*	108	*114*	*115*	*118*	108
20a. West Porlock	116.8	95	93	124	101	110	*109*	114	117	111	112	110
22c. Street	115.0	88	62	*120*	97	102	*109*	*118*	122	*115*	*118*	101
25c. Keynsham	118.1	*97*	94	*120*	110	128	*109*	*118*	*114*	*115*	109	*116*
27c. Portishead	119.1	101	*89*	120	*104*	130	*109*	*118*	*114*	*115*	*118*	134
28b. Clevedon	117.6	98	95	*120*	108	*111*	*109*	108	*114*	112	*118*	117
28d. Llandaff	117.2	98	§103	*120*	103	116	*109*	119	116	*115*	*118*	§99
32a. Tenby	116.3	99	*89*	*120*	99	103	*109*	116	*114*	*115*	*118*	103
36a. Llandilo	117.4	95	*89*	*120*	102	111	111	*118*	120	*115*	*118*	*116*
43c. Aberystwyth	117.4	97	87	*120*	102	102	115	119	109	125	*118*	115
B 6a. Timoleague	116.7	97	*89*	*110*	98	102	*109*	*108*	*115*	*109*	*113*	117
22a. Lismore	116.6	97	*89*	*110*	98	*106*	*109*	*108*	*115*	*109*	*113*	113
41a. Ferns	116.0	90	*89*	*110*	104	*106*	*109*	*108*	*115*	*109*	*113*	120
43b. Stradbally	116.4	100	*89*	*110*	*103*	114	*109*	*108*	*115*	*109*	*113*	109
C 5c. Bratton	117.2	96	*95*	*106*	101	103	101	112	*113*	*108*	*111*	132
8b. Marlborough	121.5	120	*95*	*106*	120	121	107	130	104	*108*	*122*	121
1a/e. Bournemouth	114.7	79	91	*106*	101	98	*108*	113	*113*	120	*111*	*115*
1f. Boscombe	117.2	116	91	*106*	*102*	110	*108*	120	*113*	*108*	*111*	*115*
1b. Ringwood	114.1	96	97	120	98	92	119	116	*113*	98	*111*	93
1c. Lymington	116.8	100	*95*	113	100	113	*108*	*114*	*113*	*108*	*111*	108
1i. Appleslade	114.0	97	97	99	92	108	97	111	*113*	*108*	*111*	102
3a. Shanklin	113.5	93	84	*106*	93	109	*108*	112	*113*	*108*	92	109
3e/f. Southsea	111.0	105	94	102	92	102	113	115	131	98	109	117
4b. Sherfield English	114.7	98	108	99	98	*111*	*108*	*114*	*113*	87	*111*	118
4d. Lyndhurst	116.4	*95*	*95*	104	102	*111*	105	*114*	*113*	*108*	*111*	120
6a. Havant	118.2	96	119	*106*	*102*	*111*	99	130	*113*	*108*	*111*	129
7a. Botley	115.2	92	*95*	109	100	129	*108*	115	*113*	*108*	*111*	109
7c. Hythe, S'tham't'n	112.8	76	90	95	93	*111*	*108*	*114*	*113*	*108*	*111*	*115*
7f. Sutton Scotney	117.5	95	*95*	*106*	110	110	*108*	112	128	*108*	121	118
7h. Winchester	115.1	96	*95*	*106*	96	108	*108*	*114*	*113*	110	*111*	*115*
16k. Yateley	118.0	97	*95*	112	101	*111*	107	126	*113*	*108*	*111*	*115*
20c. Maidenhead	117.6	93	*95*	112	*102*	*111*	*108*	*114*	*113*	*108*	*111*	*115*
10d. Portslade	114.1	101	98	104	102	112	94	101	*113*	119	119	116
15b/d Horsham	114.9	89	*95*	105	106	*111*	*108*	*114*	*113*	*108*	*111*	121
18a. Lewes	112.5	94	87	*106*	99	113	101	101	*113*	100	111	109
18c. Ditchling	111.0	99	92	88	102	94	109	121	*113*	*108*	*111*	99
21a. Brede	115.6	100	*95*	115	101	*111*	99	112	*113*	*108*	*111*	120
21b. Hastings	113.0	95	98	97	98	110	100	97	113	101	*111*	110
16g. Rowledge	116.1	96	*95*	*106*	98	*111*	*108*	106	*113*	*108*	*111*	121

* The *Bird* values are the mean of all actual records (excluding those abnormally obtained by interpolating for blanks either the district mean, or a considered value 111, April 21; 121 May 1; 131 May 11. † Combination of three stations Oa, b, d.

NOTE.—For reasons of space the following are omitted from the table, although Spotted Flycatcher. They, of course, appear in Table VI.

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SPRING MIGRANTS, 1925.

Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Grasshopper Warbler (*Locustella naevia*).	Reed Warbler (*Motacilla arundinacea*).	Whinchat (*Pratincola rubetra*).	Wood Warbler (*Phylloscopus sibilatrix*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Red-backed Shrike (*Lanius collurio*)	Nightjar (*Caprimulgus europaeus*).	Mean of Nos. 1 to 6.	Mean of Nos. 7 to 17.	Mean of Nos. 18 to 28.
14	15	16	17	18	19	20	22	23	24	25	26	27			
119	*119*	*110*	*121*	*126*	*121*	*123*	*123*	128	*125*	*130*	*135*	*138*	102.8	116.5	127.1
128	*119*	*110*	*121*	*126*	116	128	*123*	116	*125*	*130*	*135*	125	103.7	116.3	124.5
109	*119*	*110*	*121*	*126*	*121*	*123*	*123*	121	116	*130*	*135*	130	99.8	110.6	124.7
134	*119*	*110*	*121*	132	*121*	*123*	*123*	130	*125*	*130*	*135*	*138*	106.7	118.7	125.4
119	*119*	114	*121*	*126*	*121*	*123*	*123*	124	*125*	*130*	*135*	*138*	103.5	115.4	127.2
121	*119*	*110*	*121*	*126*	*121*	*123*	*123*	114	*125*	*130*	*135*	*138*	103.8	116.1	127.1
130	*119*	*110*	*121*	*126*	*121*	*123*	*123*	120	*125*	*130*	*135*	157	100.5	114.5	128.5
119	*119*	*110*	*121*	*126*	*121*	112	*123*	124	131	*130*	*135*	*138*	102.5	115.4	126.7
119	*119*	*110*	*121*	*126*	*121*	134	116	122	119	*130*	*135*	156	103.2	115.6	128.5
113	115	*110*	120	*126*	*121*	120	*123*	112	*125*	121	*135*	129	101.8	114.3	123.5
114	114	*110*	*121*	*126*	112	*123*	*123*	124	*125*	122	127	123	100.2	114.2	122.3
118	125	*110*	*121*	*126*	123	*123*	123	129	*125*	133	*135*	161	103.5	114.1	130.2
109	*119*	*110*	*121*	*126*	115	*123*	*123*	120	*125*	*130*	*135*	*138*	104.2	112.7	126.1
117	*119*	108	*121*	136	121	*123*	125	121	124	132	*135*	138	102.7	113.4	128.9
119	122	*110*	*121*	*126*	*121*	*123*	*123*	120	*125*	*130*	*135*	*138*	94.5	114.7	126.5
107	120	107	*121*	*126*	125	*123*	*123*	122	119	139	140	*138*	109.8	113.4	127.5
119	*119*	*110*	*121*	*126*	*121*	*123*	*123*	127	*125*	121	*135*	*138*	107.7	116.8	127.5
112	*119*	*110*	*121*	*126*	*121*	*123*	*123*	124	*125*	*130*	142	135	105.7	113.8	127.9
112	*119*	*110*	*121*	*126*	123	123	*123*	126	131	*130*	*135*	*138*	105.5	113.4	127.5
116	*119*	*110*	*121*	*126*	*121*	124	*123*	120	125	*130*	*135*	129	103.8	113.5	125.8
120	*119*	*110*	*121*	*126*	*121*	*123*	*123*	120	122	*130*	*135*	*138*	101.8	116.9	126.4
119	*119*	*110*	*121*	127	124	121	130	117	125	*130*	*135*	127	102.7	116.4	126.4
124	*117*	*120*	*121*	*115*	*121*	123	*124*	124	124	*127*	*135*	140	99.3	115.8	127.1
130	*117*	129	*121*	*115*	*121*	132	*124*	117	118	*127*	*135*	*130*	99.8	116.5	125.7
125	*117*	*120*	*121*	*115*	*121*	*120*	*124*	*125*	120	*127*	*135*	*130*	101.7	115.2	124.7
125	*117*	*120*	*121*	*115*	*121*	*120*	*124*	121	122	*127*	*135*	*130*	104.2	114.2	125.4
116	126	*119*	135	122	*122*	*117*	120	125	*132*	128	137	*131*	101.8	116.8	126.0
120	144	*119*	*123*	*117*	125	123	131	123	*132*	129	145	144	110.7	119.7	129.3
120	101	*119*	*123*	*117*	*122*	*117*	122	120	*132*	*127*	*135*	*131*	96.2	114.6	124.8
120	122	*119*	*123*	100	122	*117*	122	*123*	*132*	125	*135*	*131*	106.8	116.6	123.4
116	*117*	*119*	119	*117*	124	111	120	116	127	129	*135*	*131*	101.5	111.8	123.3
113	*117*	*119*	*123*	*117*	*122*	*117*	*124*	121	*132*	*127*	*135*	*131*	104.8	112.9	127.1
125	*117*	120	*123*	*117*	*122*	102	129	120	*132*	*127*	*135*	128	97.5	112.5	124.5
113	120	*119*	120	*117*	*122*	115	130	123	*132*	132	132	*131*	96.8	111.3	124.8
109	113	115	113	112	115	112	116	117	119	121	121	124	98.5	111.7	117.2
116	*117*	*119*	*123*	*117*	*122*	*117*	*124*	121	*132*	135	138	131	101.7	111.1	125.5
125	117	*119*	*123*	*117*	*122*	*117*	124	124	*132*	130	137	*131*	101.7	114.9	126.0
112	118	114	*123*	*117*	119	*117*	130	124	146	*127*	*135*	140	106.8	114.9	127.6
116	*117*	*119*	*123*	*117*	*122*	*117*	*124*	122	128	129	*135*	130	103.7	112.3	124.4
116	*117*	*119*	*123*	*117*	*122*	114	*124*	117	*132*	*127*	123	123	94.2	113.7	122.1
116	113	*119*	*123*	*117*	*122*	116	*124*	126	*132*	119	*135*	*131*	103.7	115.9	126.5
117	*117*	*119*	*123*	*117*	*122*	115	*124*	112	*132*	*127*	*135*	*131*	100.0	114.5	124.1
116	120	122	*123*	*117*	117	119	125	125	*132*	*127*	*135*	126	106.7	115.4	126.7
113	*117*	*119*	*123*	*117*	128	*117*	*124*	123	*132*	130	139	*131*	103.7	113.6	129.1
120	102	129	106	109	126	120	114	121	142	119	140	127	102.8	111.5	122.8
116	120	*119*	*123*	112	*122*	*117*	*124*	120	*132*	*127*	*135*	130	101.7	114.5	122.4
109	109	*119*	128	*117*	116	109	123	120	134	122	122	136	99.8	109.9	122.1
99	100	102	122	100	*122*	110	109	122	136	123	141	128	95.8	109.5	120.8
116	119	117	120	*117*	116	120	*124*	124	*132*	119	*135*	126	106.3	112.5	123.8
97	112	115	*123*	117	*122*	*117*	*124*	117	*132*	*127*	*135*	*131*	100.7	108.7	123.9
116	*117*	*119*	*123*	*117*	126	*117*	129	121	*132*	*127*	*135*	129	103.2	113.6	125.7

...rly or late), by districts, without any interpolation. The *Station* values are ...om adjacent records. Such values are printed in *italics*. 91 is April 1; 101, April 11; ...Combination of three stations 17a, b, d. § Observed at Builth Wells, Breconshire. ...included in the station means:—(5) Swallow, (9) Cuckoo, (21) Nightingale, (28)

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TABLE VII.—ARRIVAL OF

	STATIONS.	Mean Value.	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Wryneck (*Iynx torquilla*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucus*).	Yellow Wagtail (*Motacilla Rayi*).	Redstart *Ruticilla phœnicurus*).	House Martin (*Chelidon urbica*).
			1	2	3	4	6	7	8	10	11	12	13
16l.	Thursley	113.9	94	95	*106*	98	103	*108*	100	101	*108*	*111*	111
22a.	Lingfield	118.0	98	*95*	*106*	100	*111*	100	*114*	*113*	*108*	*111*	134
22b.	Warlingham	115.7	97	102	97	97	*111*	102	*114*	*113*	*108*	97	*115*
22c.	Purley	116.9	98	*95*	95	110	*111*	*108*	*114*	*113*	115	*111*	126
24a.	Lympne	116.0	105	91	100	102	*111*	*108*	*114*	*113*	*108*	*111*	106
24b.	Woodchurch	115.3	99	*95*	99	98	*111*	*108*	*114*	*113*	*108*	*111*	108
25a/c.	Maidstone	115.1	95	*95*	99	102	*111*	*108*	*114*	*113*	*108*	*111*	114
28a.	Rochester	121.7	101	89	*106*	100	107	102	132	111	*108*	115	113
D5d.	Coaley	116.1	93	*101*	*103*	90	105	110	*122*	116	105	113	100
6a.	Dymock	119.7	*98*	*101*	*103*	103	*112*	116	130	*113*	*112*	130	137
3b.	Ross	120.4	117	*101*	*103*	117	117	127	*122*	*113*	*112*	*116*	102
4b.	Staunton-on-Arrow	118.3	98	*101*	*103*	99	113	111	128	123	*112*	114	111
11b/c.	Ludlow	112.1	91	88	*103*	99	101	109	107	114	*112*	109	105
11a.	Tenbury	117.1	97	118	102	102	*112*	114	126	*113*	*112*	121	100
16b.	Wolverley	118.9	98	110	*103*	101	*112*	*112*	111	*113*	*112*	122	129
15a.	Whernalls	117.6	96	*101*	*103*	97	*112*	100	120	*113*	*112*	*116*	*113*
15c.	Stratf'd-on-Avon	118.3	103	*101*	*103*	*104*	*112*	*112*	*122*	*113*	*112*	124	110
16d.	Quinton	123.5	89	95	120	112	126	122	*122*	128	122	*116*	127
16e.	S. Birmingham	115.9	90	*101*	*103*	111	114	111	132	101	113	104	113
21b.	Erdington	119.9	113	*101*	*103*	*104*	120	*112*	*122*	*113*	*112*	*116*	122
21f.	Hall Green	121.5	122	93	*103*	112	112	125	*122*	*113*	*112*	*116*	125
26b.	Sutton Coldfield	120.6	102	122	*103*	100	116	112	124	115	116	149	*113*
19b.	Granborough	117.1	98	*101*	*103*	100	*112*	*112*	117	*113*	*112*	114	109
35a.	Somersal Herbert	117.4	99	98	*103*	102	*112*	102	*122*	*113*	*112*	*116*	116
41a.	Hebden Bridge	120.2	*100*	97	*105*	100	*114*	118	*124*	116	115	118	126
41b.	Wilsden	118.2	*100*	101	*105*	104	103	109	*124*	109	*114*	115	*114*
44d.	Mexborough	119.2	*100*	*103*	*105*	*106*	*114*	125	*124*	*115*	101	*117*	*114*
49b.	Fairburn	122.4	*100*	*103*	*105*	102	115	*114*	148	*115*	123	*117*	125
E 1c.	Barnet	114.4	97	*97*	*105*	99	*109*	99	110	*121*	*110*	110	109
4c/l.	Harpenden	116.5	95	*97*	120	101	105	116	*117*	*121*	*110*	*116*	111
4i.	Hitchin	113.1	87	*97*	102	98	100	105	121	*121*	*110*	*116*	107
7b.	Sawbridgeworth	117.6	98	120	104	97	118	108	118	125	114	120	111
7f.	Buntingford	115.1	*97*	*97*	*105*	*101*	110	*107*	111	*121*	*110*	*116*	108
*	Letchworth	114.5	87	117	102	98	100	105	121	*121*	130	*116*	109
5a.	Turvey	117.5	97	*97*	*105*	100	*109*	101	*117*	*121*	*110*	*116*	113
10a.	Maldon	117.4	*97*	*97*	133	111	*109*	112	*117*	*121*	*110*	*116*	113
11a.	Cambridge	116.8	*97*	*97*	*105*	*101*	*109*	113	*117*	*121*	*110*	*116*	*110*
17a.	Belstead, Ipswich	113.8	90	*97*	97	*101*	104	*107*	104	*121*	104	121	*110*
17c.	Ipswich	117.9	*97*	*97*	*105*	*101*	130	*107*	129	*121*	*110*	*116*	107
23a.	Bungay	117.9	92	90	104	105	109	103	116	117	119	116	105
22b.	Langford	116.0	102	88	*105*	109	113	116	110	*121*	95	*116*	112
F 9a.	Beaumaris	120.6	97	*95*	*107*	100	120	*115*	*125*	124	*117*	*117*	123
9b.	Deganwy	120.1	97	93	*107*	107	101	*115*	130	129	*117*	*117*	110
13d.	Shotwick	116.0	104	*95*	*107*	*109*	110	*115*	134	*120*	*117*	*117*	109
14a.	Barnton	115.7	104	*95*	*107*	112	96	99	115	*120*	111	*117*	105
14b.	Altrincham	119.4	*101*	*95*	*107*	116	115	*115*	*125*	125	115	*117*	118
16b.	Bramhall	121.5	103	103	*107*	112	*110*	128	120	105	*117*	*117*	125
19a.	Stockport	118.9	97	89	*107*	*109*	104	*115*	*125*	*120*	*117*	*117*	113
22b.	Ulverston	121.2	107	*95*	*107*	107	125	*115*	*125*	130	*117*	*117*	114
25a.	Ambleside	118.8	97	87	*107*	103	*110*	115	127	109	113	116	113
28c.	Mungrisdale	121.0	*101*	95	*107*	115	*110*	*115*	*125*	117	*117*	119	131

* Combinations of three stations, 8a, b, c.

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SPRING MIGRANTS, 1925—*continued*.

Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Grasshopper Warbler (*Locustella naevia*).	Reed Warbler (*Motacilla arundinacea*).	Whinchat (*Pratincola rubetra*).	Wood Warbler (*Phylloscopus sibilatrix*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift. (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Red-backed Shrike (*Lanius collurio*).	Nightjar (*Caprimulgus europaeus*).	Mean of Nos. 1 to 6.	Mean of Nos. 7 to 17.	Mean of Nos. 18 to 28.
14	15	16	17	18	19	20	22	23	24	25	26	27			
114	117	119	120	117	122	117	124	122	132	127	135	131	99.8	110.7	124.6
116	117	119	123	117	123	117	124	141	132	129	135	131	103 2	114.8	129.2
117	117	116	123	117	122	117	130	124	132	132	139	140	101.7	111.9	127.3
115	127	119	123	117	122	117	124	129	132	120	135	134	103.5	115.4	125.7
116	117	119	123	117	122	117	118	125	132	134	135	131	103.5	113.4	125.5
102	119	119	123	117	122	117	132	124	132	133	140	133	101.7	111.1	126.8
113	123	119	123	117	122	117	124	124	132	127	135	131	102.3	113.3	124.0
130	133	119	148	139	129	148	132	125	132	127	131	125	102.0	121.2	132.9
120	116	118	124	124	123	121	125	124	127	126	144	132	98.3	113.8	128.1
122	117	118	121	124	123	121	120	124	129	127	139	132	104.2	120.3	127.7
127	117	118	121	124	123	121	125	120	129	127	139	132	112.0	117.3	128.1
114	117	118	121	128	131	121	125	125	129	127	139	132	103.5	116.0	128.7
108	115	115	113	111	114	108	128	120	118	127	139	122	100.0	110.6	122.3
114	116	115	121	114	117	121	123	124	125	131	139	132	105.2	114.5	126.3
114	117	118	121	124	123	122	125	120	125	132	135	132	105.8	116.5	128.5
135	122	118	121	123	123	121	125	125	127	135	139	132	102.8	116.4	126.9
108	117	118	121	124	123	121	125	124	135	133	139	132	105.7	115.1	128.4
120	132	118	129	124	135	121	122	131	158	130	139	132	108.7	123.2	131.8
117	113	126	129	120	113	113	126	122	119	122	139	132	102.8	115.2	123.6
116	117	118	121	124	123	121	125	126	134	135	139	132	109.3	116.6	128.8
130	118	118	121	130	123	147	125	124	130	127	139	132	107.3	120.2	130.5
122	121	118	113	124	123	121	125	122	129	127	139	132	108.5	119.6	128.1
114	117	118	121	124	123	121	125	124	129	127	139	132	103.8	114.5	126.9
122	116	118	121	124	123	121	125	124	129	127	139	132	102.5	116.2	126.7
121	119	120	123	118	130	123	128	125	131	129	139	132	104.7	120.1	128.7
121	119	120	123	125	123	123	128	125	131	129	139	132	102.5	116.2	128.7
123	119	120	123	125	123	125	128	125	133	129	139	132	104.3	117.5	129.1
133	119	120	123	125	123	120	145	132	131	135	139	132	105.8	122.7	131.2
114	110	127	126	114	120	118	121	124	127	125	136	130	101.0	113.2	122.9
115	103	127	126	116	120	115	122	121	127	121	136	130	104.3	115.5	124.1
112	112	127	126	116	120	115	105	125	127	124	136	130	97.2	114.0	120.9
114	117	127	126	116	120	116	121	125	125	130	136	130	106.0	117.1	124.5
118	121	127	126	116	120	118	121	111	127	117	136	130	102.8	115.0	121.9
112	112	130	126	116	120	115	121	113	127	116	136	133	100.5	116.0	120.7
113	130	127	119	116	120	119	130	130	129	132	138	130	101.3	116.4	127.5
103	112	127	126	116	120	118	121	124	127	125	136	130	109.3	115.7	123.5
116	116	127	126	116	120	118	121	128	127	129	136	130	102.8	116.7	124.5
115	121	127	126	116	121	118	121	121	127	114	136	121	98.5	114.6	121.3
122	116	122	126	116	120	118	121	123	127	125	136	130	106.2	118.0	124.3
112	123	127	125	125	126	122	129	126	128	125	133	133	102.5	117.5	126.5
111	117	127	125	108	116	126	121	128	127	132	136	130	102.8	114.5	124.5
123	121	127	121	119	120	123	131	128	124	133	140	129	103.8	121.6	128.6
126	121	127	121	119	130	130	133	125	123	133	140	129	102.2	120.6	129.4
125	121	127	126	119	120	123	131	127	126	133	140	126	105.7	120.1	126.6
115	116	127	116	113	120	115	131	115	116	133	140	129	102.5	113.7	124.8
119	116	127	121	119	120	116	131	125	114	133	140	129	108.0	119.1	125.9
137	132	127	121	119	120	123	131	124	134	133	140	133	106.8	121.6	129.4
119	121	127	121	119	120	121	131	127	125	133	140	129	102.3	118.9	127.8
125	121	127	121	119	120	125	131	122	126	133	140	129	109.0	121.6	127.5
129	121	127	121	119	110	133	126	125	130	133	140	129	100.7	119.2	128.3
131	121	127	121	119	120	123	131	115	133	133	140	129	107.3	122.1	127.4

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TABLE VII.—ARRIVAL OF

STATIONS.	Mean Value.	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Wryneck (*Lynx torquilla*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucus*).	Yellow Wagtail (*Motacilla Rayi*).	Redstart (*Ruticilla phœnicurus*).	House Martin (*Chelidon urbica*).
		1	2	3	4	6	7	8	10	11	12	13
32a. Alston	120.3	*101*	*95*	*107*	111	105	120	*125*	*120*	*117*	*117*	113
G 41a. Bessbrook	116.5	97	*89*	*110*	*109*	*105*	*110*	*111*	*116*	*109*	*113*	*114*
41c. Scarva	114.0	95	*89*	*110*	103	93	*110*	*111*	*116*	*109*	*113*	121
35c. Warrenpoint	115.3	*98*	*89*	*110*	97	*105*	*110*	*111*	*116*	*109*	*113*	113
50f. Woodburn	114.4	96	91	98	108	102	*110*	*111*	116	*109*	111	108
54a. Hazelbank	114.9	94	86	*110*	*109*	101	108	111	116	109	116	113
Isle of Man.*												
H 0a. Douglas	118.2	76	88	*115*	98	99	*118*	*120*	115	*120*	*120*	*117*
1a. Kirkmaiden	119.3	*102*	*101*	*115*	95	102	100	*120*	106	*120*	*120*	105
2a. Marks	121.9	*102*	104	*115*	118	*111*	*118*	*120*	110	*120*	*120*	*117*
27b. Larkhall	124.5	*102*	*101*	*115*	109	120	*118*	*120*	111	120	*120*	120
I 11c. Grimsby	122.0	102	*102*	*116*	102	*115*	*118*	129	*117*	116	*120*	133
12a. Howdenshire	122.1	*106*	*102*	*116*	103	115	134	136	*117*	*117*	98	123
14a. York	118.1	95	103	*116*	98	102	109	109	111	*117*	*120*	109
18a. Middleton-in-Teesdale	121.2	*106*	95	106	110	129	114	*123*	*117*	107	120	*116*
30a. Thornton Dale	120.7	96	89	*116*	103	115	118	128	*117*	*117*	119	118
24b. Darlington	121.1	*106*	*102*	*116*	107	*115*	*118*	*123*	123	112	123	113
33b. Chopwell	120.5	*106*	120	*116*	109	112	111	*123*	116	*117*	116	113
19a Haltwhistle	120.0	*106*	83	*116*	109	114	*118*	*123*	117	*117*	124	121
26a. Catcleugh	122.8	113	92	*116*	117	111	128	*123*	116	*117*	120	117
38c. Lemmington	122.8	106	103	126	117	112	*118*	117	131	122	119	115
J 6b. Jedburgh	123.9	*103*	*103*	*115*	117	*118*	*123*	*115*	*111*	*122*	*123*	122
4a. Selkirk	123.2	96	102	*115*	109	115	123	*115*	115	*122*	123	117
10a. West Foulden	122.1	*103*	*103*	*115*	105	109	*123*	*115*	*111*	*122*	*123*	116
15a. Dunfermline	125.1	*103*	115	*115*	125	131	*123*	*115*	*111*	*122*	*123*	132
20a. Tummel Bridge	124.6	*103*	*103*	*115*	*113*	*118*	*123*	*115*	*111*	*122*	*123*	*122*
35b. South Fowlis	124.5	*103*	*103*	*115*	118	128	*123*	*115*	*111*	*122*	*123*	130
36a. Cabrach	124.0	*103*	103	*115*	117	122	122	111	117	*122*	*123*	124
39a. Dunlugas	120.3	*103*	91	*115*	92	99	*123*	118	100	*122*	*123*	113
K 27b. Kirkhill	127.7	*105*	107	*116*	125	131	*121*	*120*	*119*	*124*	121	146
Total records used = 3104	...	201	99	58	198	117	76	83	60	54	49	180
Mean of—												
A (8) England S.W.	117.6	97	89	120	104	111	109	118	114	115	118	116
C (5) England S.E.	115.7	95	95	106	102	111	108	114	113	108	111	115
D (4) Midlands	118.6	99	103	103	104	113	113	123	114	113	117	113
E (3) England E.	116.0	97	97	105	101	109	107	117	(121)	110	116	110
F (7) England N.W.	120.0	101	95	*107*	109	110	115	125	120	117	(117)	116
G (9) Ireland N.	114.7	98	89	[98]	109	105	[108]	[111]	(116)	[109[	(113)	114
I (2) England N.E.	121.5	106	102	(116)	109	115	118	123	117	117	120	116
J (1) Scotland E.	122.9	[96]	103	*115*	113	118	(123)	(115)	111	*122*	[123]	122
Mean, 1925	118.6	98.4	97.3	108.0	107.8	112.7	112.2	116.2	115.4	113.6	117.3	117.7
Day of Month	A.29	A. 8	A. 7	A.18	A.18	A.23	A.22	A.26	A.25	A.24	A.27	A.28
Average 10 yrs., 1914-23	117.2	95.1	96.8	103.3	105.2	110.0	111.6	113.1	115.1	115.9	116.0	117.2
„ N.H.J., 1877-96	112.3	94	93	102	103	106	107	110	117	109	112	111
Diff. from 10 yrs.' Avge.	+1½	+3½	+½	+4½	+2½	+2½	+½	+3	+½	—2½	+1½	+½

* Not included in the means for District H.

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SPRING MIGRANTS, 1925—*continued.*

Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Grasshopper Warbler (*Locustella nævia*).	Reed Warbler (*Motacilla arundinacea*).	Whinchat (*Pratincola rubetra*).	Wood Warbler (*Phylloscopus sibilatrix*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift. (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Red-backed Shrike (*Lanius collurio*).	Nightjar (*Caprimulgus europæus*).	Mean of Nos. 1 to 6.	Mean of Nos. 7 to 17.	Mean of Nos. 18 to 28.
14	15	16	17	18	19	20	22	23	24	25	26	27			
123	*121*	*127*	*121*	127	*120*	*123*	134	128	*126*	*133*	*140*	*129*	104.8	120.5	128.5
122	*117*	*125*	*123*	*111*	*122*	*111*	*126*	126	120	*125*	*133*	*123*	103.3	116.5	123.6
123	*117*	*125*	113	103	*122*	102	103	124	118	*125*	*133*	*123*	99.5	116.2	119.8
132	*117*	*125*	*123*	*111*	*122*	*111*	*126*	125	113	*125*	*133*	*123*	99.3	117.4	121.8
109	116	*125*	*123*	111	*122*	111	*126*	119	116	*125*	132	*123*	101.2	113.4	122.7
124	*117*	118	*123*	111	*122*	120	*126*	122	115	120	*133*	118	99.7	115.2	122.9
117	*127*	*126*	*124*	122	*124*	*125*	117	*135*	*127*	*131*	*135*	*131*	95.8	120.1	128.5
124	*127*	*126*	*124*	*125*	*124*	*125*	*127*	*135*	*127*	*131*	*135*	*131*	104.2	117.6	129.2
124	*127*	*126*	*124*	132	*124*	*125*	*127*	*135*	*127*	*131*	*135*	*131*	109.8	120.6	129.8
124	*127*	*126*	*124*	*125*	*124*	106	*127*	142	127	*131*	*135*	*131*	110.8	119.3	128.1
116	*126*	*129*	*127*	122	*126*	117	126	*128*	*128*	137	*139*	*131*	108.2	122.7	128.8
122	129	*129*	130	*121*	*126*	121	130	124	130	134	*139*	*131*	107.3	122.7	129.5
109	*126*	*129*	130	*121*	*126*	129	*126*	128	123	123	*139*	126	103.8	116.4	127.6
121	*126*	*129*	*127*	128	131	*123*	*126*	134	131	*129*	*139*	*131*	107.0	119.6	130.5
125	*126*	*129*	*127*	*121*	122	*123*	128	*128*	130	128	*139*	*131*	105.0	121.6	128.5
115	*126*	*129*	*127*	*121*	*126*	*123*	*126*	124	130	*129*	*139*	*131*	108.2	120.9	128.4
116	*126*	120	*127*	120	115	*123*	116	131	125	*129*	*139*	131	112.7	118.9	126.5
121	123	*129*	*127*	116	*126*	125	119	*128*	122	*129*	*139*	*131*	105.0	122.0	126.2
133	*126*	*129*	*127*	122	130	*123*	128	*128*	*128*	*129*	*139*	*131*	110.0	123.5	129.2
123	*126*	138	*127*	117	*126*	*123*	131	125	126	*129*	*139*	126	111.8	122.7	128.9
128	*128*	*130*	*128*	*123*	120	*137*	*129*	129	*128*	*133*	*140*	*133*	111.3	124.2	130.4
126	*128*	*130*	*128*	130	129	137	130	124	*128*	*133*	*140*	*133*	107.7	122.6	132.3
126	*128*	*130*	*128*	*123*	*124*	*137*	*129*	131	128	*133*	*140*	*133*	107.3	121.5	130.9
126	*128*	*130*	*128*	*123*	*124*	*137*	*129*	125	140	*133*	*140*	*133*	116.0	123.7	131.4
130	*128*	*130*	*128*	*123*	*124*	135	138	136	*128*	*133*	*140*	143	111.2	123.3	133.3
126	*128*	*130*	*128*	*123*	*124*	*137*	*129*	134	*128*	*133*	*140*	*133*	115.3	123.5	130.5
126	*128*	*130*	*128*	124	*124*	136	*129*	*129*	*128*	*133*	*140*	*133*	113.3	123.0	130.7
121	110	*130*	*128*	115	122	143	119	120	134	*133*	*140*	*133*	104.8	119.0	130.0
120	136	*131*	*129*	*125*	129	*137*	*129*	150	*129*	*135*	*142*	*133*	118.5	126.5	134.2
141	68	26	29	52	55	63	61	221	99	81	25	60	...	...	...
119	119	110	(121)	126	121	123	123	123	125	130	135	138	104½	115½	127
116	117	119	123	117	122	117	124	123	132	127	135	131	101½	114	125½
120	118	118	122	124	123	122	126	124	131	128	139	(132)	105	117	127½
115	116	127	126	116	120	118	121	123	127	125	(136)	130	102	116	123½
123	121	*127*	(121)	119	(120)	123	131	124	126	[133]	*140*	(129)	105½	120	128
123	[116]	[118]	[113]	111	*122*	111	[103]	124	116	[120]	[132]	(123)	101½	104½	120½
121	126	(129)	127	121	126	123	126	128	128	129	*139*	131	110	121	128½
126	[110]	*130*	*128*	123	124	137	129	129	128	*133*	*140*	[143]	110	121½	132½
121.3	119.9	125.7	121.9	121.0	123.1	120.7	123.2	127.3	126.3	127.4	135.4	135.2	105.8	116.9	127.2
My. 1	A.30	My. 6	My. 2	My. 1	My. 3	My. 1	My. 3	My. 7	My. 6	My. 7	My15	My15	A. 16	A. 27	My. 7
119.0	119.1	119.6	119.7	120.9	121.4	121.8	123.9	123.9	124.4	126.8	130.7	132.7	103.4	116.5	125.8
113	118	118	...	113	119	115	125	125	121	123	133	129	100.3	113.5	122.0
+2½	+1	+6	+2	0	+1½	−1	−½	+3½	+2	+½	+4½	+2½	+2½	+½	+1½

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TABLE VIIa.—Additional Bird Records.

District.	First Song, Missel Thrush.	First Song, Blackbird.	First Song, Lark.	Last Song, Cuckoo.	Last Swift.	Last Sand-Martin.	Last House-Martin.	First Redwing.	First Fieldfare.
Channel Isles . .	(7)	28	(43)	(181)	(225)	...	(299)	[315]	...
A (8) England S.W.	8	26	31	174	226	261	278	298	302
B (10) Ireland S. .	20	50	64	172	(230)	[272]	(273)	(293)	310
C (5) England S.E. .	5	28	29	177	229	273	286	298	298
D (4) Midlands. .	11	22	37	174	226	257	279	293	298
E (3) England E .	13	30	21	178	235	267	285	281	290
F (7) England N.W.	11	35	37	177	228	(283)	273	288	293
G (9) Ireland N. .	9	35	47	171	232	[259]	261	301	295
H (6) Scotland W. .	(13)	17	49	[185]	[201]	...	...	[285]	[312]
I (2) England N.E. .	18	35	40	180	226	269	274	288	287
J (1) Scotland E. .	33	43	42	174	240	(256)	267	288	283
K (0) Scotland N. .	[47]	(57)	[47]	(178)	[247]	[263]	[266]	[302]	(294)
Isle of Man . .	...	...	[53]	[201]	[226]	[251]	[256]	[317]	[315]
Records Used . .	155	207	164	125	118	40	121	67	84
Mean of All . .	17.1	34.4	40.4	176.4	229.1	266.0	274.2	292.3	296.5
Month and Day .	J. 17	F.3	F.9	Je. 25	Ag. 17	S. 23	O.1	O. 19	O. 24
Average, 11 yrs., 1915-25	18.4	41.5	42.2	179.2	230.0	271.3	280.0	294.5	299.3
Month and Day .	J.18	F.10	F.11	Je.28	Ag. 18	S. 28	O.7	O. 21	O. 26

( ) Indicates mean of two observations only. [ ] A single record.

(*Continued from page* 306.)

cankered at the core; holly berries scarce as a rule. G55a ascribes poor fruit crops to previous sunless years. Blackberries alone stood out; so C1b, E4c, F11e, I33b, "almost a record," I36a, "best for years."

Crops. Grass was good all the year and hay, unless spoilt in late districts. As a rule grain reports were average; roots good (except early turnips) and potatoes. D5d, early garden and field crops drowned in April, May sowings parched in June; July sowings drowned again. C10d, onions and carrots fail from pests; peas partial. G55a, worst harvesting in memory of middle aged. In District I, potatoes suffered badly from Nov. frosts; 19a, frozen in tons; broccoli, cabbage, etc., frozen off. J38a, remarkably early and quickest harvesting in 30 years. But earlier districts often report sprouting and soft grain.

General Bird Notes. Early cuckoos often noted; A0a, 1st in March in 37 years; *cf.* Table VI.; also A11c (Feb. 7), B22b, C3b. At A1a cuckoo call at 5 a.m. repeated 1,113 times, then with short pauses 116 more. Increases are recorded. Buzzards (now protected) often noted; A5c, fight with ravens over rat; 6a, nine at once; 17d, also ravens and hawks; etc. More corncrakes in places; B50a, arrived dazed and tired, some caught by cats; also warblers and other insect feeders; C18c, more than for years, also gold- and bullfinches; goldcrests; redwings, D15c, more than for 40 years; goldcrests, snipe, woodcock; I33b, never so many of the thrush tribe. But elsewhere scarcity noted, especially corncrake, A27c, none; A21c, no wryneck; spotted flycatcher; whinchat (H27b, rarer yearly, no wood wrens); nightjar. C3f, July drought caused apple damage by jays, thrushes, blackbirds. First instances of nesting reported, A33a, dipper; B43b, long-tailed tit, 1st known for 50 years; I19a, grasshopper warbler. A24d notes mating of cock blackbird and hen thrush,

(*Continued on page* 316.)

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TABLE VIII.—Observations of Trees and Shrubs taken at St. Michael's, Tenbury, Worcestershire, 1925, by Frederick Lowe.

Date given by day of year. For equivalent monthly dates see explanation on page 292.

Common Name.	Latin Name.	First Flower.	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
1. Alder	*Alnus glutinosa*	70	121	138	261	301	310	292
2. Apple (Wild)	*Pyrus malus*	124	115	125	248	281	295	281
3. ,, (Cultivated)	*Pyrus malus sativus*	130	105	134	234	271	295	242
4. Ash	*Fraxinus excelsior*	130	139	154	249	281	298	280
5. ,, (Mountain)	*Pyrus aucuparia*	134	97	119	238	271	310	221
6. Acacia	*Robinia pseud-acacia*	173	117	151	254	292	302	280
7. Almond	*Amygdalus communis*	67	84	119	244	298	307	301
8. Berberis (Dar)	*Berberis Darwinii*	45	105	125	...	...	...	211
9. ,, (Aqui)	*Berberis aquifolium*	17	110	125	...	...	...	220
10. Barberry	*Berberis vulgaris*	134	74	115	248	295	310	244
11. Blackthorn	*Prunus spinosa*	90	102	120	255	277	298	263
12. Birch	*Betula alba*	130	108	124	248	287	307	256
13. Beech	*Fagus sylvatica*	134	112	125	230	293	301	253
15. Box	*Buxus sempervirens*	54	69	118	...	...	...	...
16. Currant (Black)	*Ribes nigrum*	109	74	112	226	268	315	184
17. ,, (Red)	*Ribes rubrum*	107	97	117	226	266	305	184
18. Chestnut (Horse)	*Æsculus hippocastanum*	134	97	116	249	272	301	273
19. ,, (Spanish)	*Castanea vesca*	193	122	136	254	282	306	274
20. Cherry (Wild)	*Prunus avium*	99	100	123	248	274	293	206
21. ,, (Bird)	*Prunus padus*	141	117	129	242	274	295	206
22. ,, (Cultivated)	*Cerasus vulgaris*	103	103	129	227	276	298	182
23. Cypress (Common)	*Cupressus sempervirens*	154	126	151	...	...	...	...
24. Cedar	*Cedrus libani*	263	108	134	(Cas	ting	175)	317
25. Dogwood	*Cornus sanguinea*	163	118	132	189	283	308	278
26. Deutzia	*Deutzia crenata*	159	12	119	254	298	320	248
27. Elm (Common)	*Ulmus campestris*	59	135	154	267	300	332	132
28. ,, (Cornish)	*Ulmus stricta*	87	121	133	255	300	321	123
29. ,, (Cork)	*Ulmus suberosa*	66	133	146	255	287	317	134
30. ,, (Wych)	*Ulmus montana*	54	115	130	228	272	301	134
31. Elder	*Sambucus nigra*	142	17	102	227	272	308	235
32. Fir (Spruce)	*Abies excelsa*	103	122	139	(Cas	ting	223)	...
33. ,, (Scots)	*Pinus sylvestris*	134	144	151	(Cas	ting	223)	...
34. Gooseberry	*Ribes grossularia*	94	60	95	226	260	293	182
35. Gorse	*Ulex europæus*	28	82	108	...	...	...	219
36. ,, (Dwarf)	*Ulex nanus*	197	123	143	...	...	...	...
37. Hazel	*Corylus avellana*	27	98	118	226	287	302	248
38. Hawthorn	*Cratægus oxyacantha*	137	73	102	230	271	299	244
39. Holly	*Ilex aquifolium*	139	134	151	(Cas	ting	157)	297
40. Honeysuckle	*Lonicera caprifolium*	139	10	95	225	268	305	219
41. ,, (Wild)	*Lonicera periclymenum*	157	12	97	244	283	313	244
42. Ivy	*Hedera helix*	256	102	130	(Cas	ting	95)	51
44. Jasmine (Yellow)	*Jasminum nudiflorum*	253	71	103	237	277	303	...
45. ,, (White)	*Jasminum officinale*	186	120	138	272	283	332	...
47. Laburnum	*Cytisus laburnum*	137	104	120	198	298	310	269
49. Laurel (Portugal)	*Cerasus lusitanica*	163	98	134	(Cas	ting	120)	240
50. ,, (Spurge)	*Daphne laureola*	25	32	108	(Cas	ting	91)	213
51. ,, (Variegated)	*Aucuba cerasus*	134	108	145	(Cas	ting	117)	...
52. ,, (Common)	*Cerasus laurocerasus*	96	113	136	(Cas	ting	104)	268
53. Larch	*Pinus larix*	91	88	116	269	298	311	258
54. Lilac	*Syringa vulgaris*	133	90	114	249	287	298	...
55. Lime	*Tilia europæa*	185	130	138	236	270	287	259
56. Lavender	*Lavendula vera*	198	76	120	(Cas	ting	227)	280
57. Maple (Field)	*Acer campestre*	133	118	132	242	272	292	273
58. ,, (Norway)	*Acer platanoides*	115	122	132	244	277	287	273
59. Medlar	*Mespilus germanica*	144	86	114	249	274	298	303
60. Mezereon	*Daphne mezereum*	1	37	100	225	276	298	181
61. Mistletoe	*Viscum album*	54	151	183	(Cas	ting	232)	314

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TABLE VIII.—Observations of Trees and Shrubs taken at St. Michael's, Tenbury, Worcestershirs, 1925, by Frederick Lowe—*continued*.

Common Name.	Latin Name.	First Flower.	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
62. Oak (Robur)	*Quercus robur*	116	116	134	249	301	342	277
63. „ (Sessile)	*Quercus sessiliflora*	117	116	135	249	293	307	277
64. Poplar (White)	*Populus alba*	88	121	133	254	287	298	120
65. „ (Grey)	*Populus canescens*	97	139	154	255	296	303	125
66. „ (Black)	*Populus nigra*	85	125	134	248	272	297	114
67. „ (Lombardy)	*Populus fastigiata*	93	118	132	249	292	300	116
68. „ (Aspen)	*Populus tremula*	121	124	133	248	287	302	130
69. Privet	*Ligustrum vulgare*	179	69	127	(Casting		182)	305
70. Pear (Common)	*Pyrus communis*	99	103	125	235	271	293	277
71. Plum (Common)	*Prunus domestica*	97	102	120	230	271	284	236
72. „ (Pershore)	*Prunus Pershorum*	103	103	123	231	273	284	236
73. Quince	*Cydonia vulgaris*	144	91	112	263	295	303	300
74. Ribes	*Ribes floridum*	72	82	98	230	274	287	...
75. Rosemary	*Rosmarinus officinalis*	88	28	97	(Casting		228)	241
76. Raspberry	*Rubus idæus*	140	59	104	224	274	311	181
77. Rose (Guelder)	*Viburnum opulus*	156	119	140	237	272	302	228
78. „ (Field)	*Rosa arvensis*	167	71	103	193	258	305	243
79. „ (Dog)	*Rosa canina*	150	79	102	201	271	316	247
80. Service (Wild)	*Pyrus torminalis*	155	138	145	254	293	308	259
81. Snowberry	*Symphoricarpus racemosus*	145	84	99	254	298	311	255
82. Syringa	*Philadelphus coronarius*	155	87	103	228	268	293	246
83. Spindle	*Euonymus europæus*	143	91	115	228	283	298	272
84. Sycamore	*Acer pseudo-platanus*	133	103	126	247	277	297	264
86. Willow (Goat)	*Salix caprea*	63	102	123	235	282	308	148
87. „ (Common)	*Salix fragilis and viminalis*	120	106	122	247	278	322	147
88. „ (White)	*Salix alba*	123	110	124	254	293	323	158
89. Walnut	*Juglans regia*	135	108	139	236	277	292	279
90. Yew	*Taxus baccata*	35	115	139	(Casting		172)	235

Trees generally in full leaf, May 28 (128). Autumn tints beginning, September 25 (268). First heavy fall of leaf, October 7 (280). Full tints, October 28 (301). Trees generally leafless, November 18 (322)

Difference from 10 year Averages of Seven Selected Trees.

13. Beech	+ 1	− 1	0	+ 3	+ 4	−12	− 2
18. Chestnut (Horse)	+ 7	− 2	− 1	+ 2	− 8	− 1	+ 6
27. Elm (Common)	+ 5	+11	+ 9	0	−10	+ 1	+ 9
37. Hazel	− 3	− 5	− 7	−10	− 1	−12	+ 2
38. Hawthorn	+11	− 5	− 5	− 9	−15	− 6	+ 7
57. Maple (Field)	0	− 2	0	− 7	−11	−14	+ 4
84. Sycamore	+14	− 2	+ 5	+ 3	−10	− 6	+ 1
Mean of the 7	+ 5	− 1	0	−2.6	−7.3	− 7	+ 4

(*Continued from page* 314.)

fledglings like dark song thrushes. Records of wild geese very common; I20a, vast flocks, Nov. and Dec. Heavy bird losses from Nov. and Dec. frosts, especially in N; I19a, picked up scores of skylarks, redwings, fieldfares, wild fowl driven to Tyne and blackcock to low ground. Swallow reports mostly indicate decrease, *e.g.*, A13c, C1b, C3a, E4c, H27b. K28a, no swallows, driven off by starlings. There are rare exceptions. House and sandmartins less affected; swifts oftener more numerous.

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TABLE IX.—Observations of Plants and Birds taken at Hevingham, Norfolk, 1925, by Major H. S. Marsham.

Plants. (First Flowering, Fl., or Leafing, L.)	Average. All Years.	Average. 35 Years, 1751-85.	Average. 35 Years, 1891-1925.	1925.	Difference from Average, 1891-1925.
*Snowdrop Fl. . . (146)	16	19	19	6	— 13
Wood Anemone Fl. (121)	85	91	79	60	— 19
*Hawthorn Fl. . . (144)	132	131	132	138	+ 6
Turnip Fl. . . . (118)	96	96	108	96	— 12
Hawthorn L. . . (152)	68	72	71	46	— 25
Sycamore L. . . (142)	93	96	90	87	— 3
*Birch L. . . . (142)	94	92	97	106	+ 9
Elm (Common) L. (115)	95	90	102	95	— 7
Mountain Ash L. . (132)	96	96	96	103	+ 7
*Oak L. . . . . (145)	115	118	110	110	0
*Beech L. . . . (145)	113	116	113	109	— 4
*Horse Chestnut L. (140)	94	96	96	101	+ 5
Chestnut L. . . . (122)	110	115	100	106	— 3
Hornbeam L. . . (127)	97	103	101	111	+ 10
Ash L. . . . . (125)	119	122	118	123	+ 5
*Lime L. . . . . (134)	104	105	102	104	+ 2
Maple L. . . . . (85)	107	110	107	113	+ 6
Average of all 17 . .	96	100	97	95	— 2

Birds, &c. (First Appearance or Song).	Average. All Years.	Average. 35 Years, 1751-85.	Average. 35 Years, 1891-1925.	1925.	Difference from Average, 1891-1925.
Swallow . . . . (153)	109	105	113	111	— 2
Cuckoo . . . . (158)	115	115	113	113	0
Nightingale . . . (118)	116	117	118	...	...
Nightjar . . . . (68)	144	142	...	...	...
Thrush . . . . (131)	27	37	28	37	+ 9
Ringdove ‡ . . . (104)	53	54	...	129	+ 2
Rooks Build . . (147)	61	64	62	56	— 6
Young Rooks . . (144)	102	102	104	109	+ 5
Yellow Butterfly . (128)	79	71	91	97	+ 6
Frogs Croak . . (143)	83	82	89	98	+ 9
Average of all 10 . .	89	89	91½	...	...
Comparison with the Society's Series.					
*Mean of 7 Plants . .	95	97	96	96	0
Mean of Society's 7 Plants (Dist. E.). †	...	...	93	91	— 2
Swallow (Society's Mean in Dist. E)	...	...	109	104	— 5
Cuckoo (Society's Mean in Dist. E)	...	...	111	110	— 1

* The seven plants used for comparison are marked *.

† The first seven plants, hazel to hawthorn, in the Society's list.

‡ Until 1915 this referred to *any* pigeon cooing, but is now strictly confined to the Turtle Dove. The average for the last 11 years is 127 (May 7).

The bracketed figures in the names column show the actual number of years observed since the record commenced in 1736.

Other Vertebrates. A2d, lamb losses from snow, Feb. 24/7; A20c, toad, 15; 34c, grass snake, 87; 43c, lizard, 53; slow worm, 77; C11, adder, 74.

Frog-spawn. 17 records received give mean date of 73 (March 14).[3]

Insects. With the coming of spring, early scarcity seems to have been universal. B14a, no humble bee seen; A15b, nor mayflies, etc., till Aug. Bee records often affected; K27b, none till 140, despite careful watch; so wasp records, in parts practically none; elsewhere later on, abundant; C7a, plague in Sept. among hothouse grapes. C7a, no dragon flies. Butterfly scarcity specially noted. But Whites, especially Large Whites, often grew troublesome in Aug. Exceptionally some kinds were unusually frequent, *e.g.*, A33a; C3f, meadow brown; C7e, also bees, humble bees and several butterflies not seen for years; E8b, also cockchafers and hymenoptera.

Pests. Little potato disease. A25c, serious increase of plum silverleaf. E8b, few fungoid troubles. But weeds! B14b, smothered potatoes,

[3] Correction: For March 1, on p. 330 of Report for 1924, read March 21.

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instead of usual reverse. In most parts oaks were almost immune from *Tortrix viridana*. Serious aphid trouble accompanied June drought, including cuckoo spit. A27c, blight on everything and everywhere, despite host of insecticides. Codlin moth, E4c, I33a. J35b, Pine Sirex appears for first time.

THE MARSHAM RECORDS.

The 1925 observations and the principal averages are given in Table IX. Of the 17 plant records in 1925, 8 were earlier and 8 later than the 1891-1925 average. The mean date of the 7 chief plants exactly equalled it, though the same in the Society's list for Eng. E was two days early. As with the latter, the earliness was most marked in Jan. and Feb., lateness appearing in April; the mean value to April 10th being −3 days, afterwards +4 days. Both the Marsham and the Society's (Eng. E) swallow records were early (by two and five days), while in each case the cuckoo date was practically normal. The average for all the 17 plant events in both the 35-year periods (1751-85 and 1891-1925) is later than that for the whole period; for birds, etc., only for 1891-1925.

SUMMARY.

We suggest that the outstanding features of the year 1925 are:—(1) the marked effect of the mild winter, bringing fruit blooming into the cold spell from mid-April through early May; (2) the hurtful result of the June drought, particularly on belated spring-sown crops and poorly set fruits; (3) the exact cancelling out of rather extreme opposite divergences in the means of warmth, temperature, sunshine and flowering, and of migrants which were only a day late; (4) the very practical illustration by isakairs of another type of divergence from the average, which occurred regionally; (5) the unexpected progressive relation between the arrival dates of cuckoo and swallow; (6) the frequent and well-authenticated records of early cuckoos; (7) the publication of the Marsham records, as summarized in Table IX., unique in the long period covered and as carried on from father to son; and (8) the very gratifying response to our proposals through *Nature* for closer international phenological collaboration, especially throughout Europe.

DISCUSSION.

Mr. L. C. W. Bonacina said he was rather puzzled about the isakairs for 1893 which had a very hot spring and early summer. Summer temperature started in April and yet the earliness decreased from west to east. One would think that the effect of continentality would have been a heating one that season and that there would have been earliness increasing from west to east. He wondered whether it would be possible to divide up the plants (we have twelve plants, from the hazel to the greater bindweed) as far as the horse chestnut into a late winter category and the other six into an early summer category, so that the relationship between the two sets could be observed. It was puzzling that the earliness should decrease from west to east in such a very hot season as 1893. The explanation seems to be that the hot spring and early summer of 1893 were characterized by a severe drought, and that it

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was lack of moisture which held vegetation back in the eastern districts. He thought that these reports increased in value and grew more complex year by year. Possibly if this Society could co-operate with the Ecological Society at Cambridge it would be helpful, because there was no doubt but that habitat was a powerful factor in determining the earliness or lateness of particular groups of plants.

Mr. R. INWARDS remarked that as regards the birds, he would like to ask Mr. Clark whether there were any data as to where they came from, the route taken by them, how many times they stopped on their journey, and when they arrived. To his knowledge the small birds were accustomed to wait on the coast near Gibraltar for fair weather to get them over to Africa, and he believed it was also the case in Morocco on their return.

The PRESIDENT (Sir Gilbert Walker) asked whether there was any mechanism for teaching observers how to identify birds, either by their appearance or their song.

Mr. N. W. THOMAS asked what exactly the Phenological Committee meant when it spoke of a first appearance. He had observed for some years in succession, swallows passing over but not stopping in his own locality. Was that to be reckoned as a first appearance? Was it necessary for recording purposes that they should actually stop in the locality?

Mr. I. D. MARGARY said in reply to the President that there were one or two books giving quite good hints for observers of birds. One was by the brother of the Lewes observer, and identified the song of birds with certain sounds; it was called *Bird-Song*, by Morris. It gave various details about the songs of the different birds which an ordinary person could follow and from which he could get quite a useful working knowledge. In another book called "Songs of the Birds," an attempt was made to reproduce the songs by a succession of human syllables, and from that source he had learnt a good deal himself, but he could not recall the name of the author.

As regards the point about the isakair map for 1893 and the decreasing earliness eastwards, that seemed clearly shown on the map for the whole twelve plants. He agreed that it would be a good thing to reduce the length of the period and cut it into a late winter and early spring half, and an early summer half. But there would be difficulty in doing so as it would mean making two maps and the Committee had to consider space and expense. Perhaps a tentative effort might be made in that direction. They were hoping to get the 35-year completed average isophenes, and they also hoped to work out the isophene maps for all the preceding years, as yet undrawn, and then to get out similar isakair maps for those years, and they would be glad of any suggestions as to suitable periods for the two halves before they proceeded with the work. The Committee would welcome criticism of the isakair maps and suggestions as to means of acquiring useful data. As regards observers, they wanted more in Scotland and in the south and west of Ireland and in Central Wales. It had occurred to him whether it would not be possible for Fellows in those parts to assist the Society in endeavouring to find suitable observers in their own localities. The experience of the Committee had been that there were potential observers in every locality, and if Fellows would take up the question of phenological observations and interest themselves in it to

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the extent of putting it before their neighbours, he was sure there would be an increase in the number of next year's observers. It was the personal introduction which counted for so much.

One more point remained for him to mention: it was a personal one. He wished to refer to the fact that whereas Mr. Mawley had run the Phenological work for the first 21 years down to 1910, since that date it had been carried on by Mr. Clark, and this was his 15th annual report. He thought that ought to be borne in mind. The work had grown very much since Mr. Clark had taken it on, and he had given a very considerable amount of time to the Report and to the correspondence connected with it, with which he dealt himself, especially with the foreign correspondence. He felt sure the Society realized what it owed to Mr. Clark for this work, for, of course, it was a great thing to have continuity of tenure in running the series from year to year.

Mr. R. Inwards remarked that with regard to the songs of birds, there was a book (*The Music of Nature*, by Wm. Gardiner, 8vo., 1843) which gave in musical notation the songs of many of our birds.

The President (Sir Gilbert Walker) said that in relation to the Brückner cycle, it would be very interesting to have any figures to indicate the general character of the past 35 years. He noticed that the previous extreme years were 1891 and 1893, separated by two years instead of seventeen as they would if the cycle were dominant.

Mr. J. E. Clark, in reply, said he again thanked the Society for the kind way in which they received the Committee's Report. He thought some of the questions had been answered by his colleagues. As regards the year 1893, it wanted further working out, but the average of all the twelve plants was given. The other point raised by Mr. Bonacina was about the Ecological Society. He had been in communication with them, but he would try again to see if any favourable results could be obtained from collaboration. As to where the birds started from and when, he was afraid he was not an ornithologist, and although he had a great interest in the subject, he could not pretend to say very much on it. The first appearance is always a most difficult thing to decide. With regard to birds, considering that we can hardly expect all observers to discriminate between passing and stopping birds, we ask for their first appearance. If the date of one arrival did not harmonize with the date of other arrivals in the same district, it was usual to ignore it. If an observer finds he has an arrival date which by reason of its earliness is out of the usual, he will do well to look for the next arrival and see if it does not correspond more nearly to the usual date given and enter that accordingly on his form, while noting the other. The same idea applies to the plants. The observer is instructed to take some plant or group that is growing under normal conditions and to observe the first flower which opens when, but only when, other flowers on the same plant or group are also ready to open. He knew that the selection of normal specimens was most difficult, and he had lately found to his regret that one of the Committee's observers from the very beginning had continued the practice of the earlier series of observing the first seen. Besides these Preston records from 1875, the same was done in the 22 years of the Floral Calendar from 1877. Observers ought to take the observations from a plant or group which could be supposed to represent the normal characteristics of the district and not from one unduly exposed or sheltered.

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PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 17, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

FREDERICK ELMES, Cedric School, Salisbury, S. Rhodesia;

Sir RICHARD GREGORY, D.Sc., F.R.A.S., F.Inst.P., 17, Grosvenor Road, S.W.1;

WILLIAM HAYNES, 5, Alexandra Road, Reading;

WILLIAM JAMES, Middle East Headquarters, R.A.F., Villa Victoria, Cairo;

Captain W. N. McCLEAN, A.M.Inst.C.E., M.I.Mech.E., 1, Onslow Gardens, S.W.7;

ERIC MORRISON MACKAY, Sub-Lieut. R.N.R., Lingerwood, Newton Grange, Midlothian;

WILLIAM E. F. MACMILLAN, 42, Onslow Square, S.W.7;

JOHN FREDERICK MARSHALL, M.A., Seacourt, Hayling Island, Hants;

JOHN RADFORD, Sub-Lieut. R.N.R., Scalpcliffe Road, Burton-on-Trent;

JAMES B. G. ROWLAND-HILL, Homersham Road, Kingston Hill, Surrey;

PERCY JOHN SPILLETT, Homedale, Stanpit, Christchurch, Hants;

Miss JEAN MARGARET WORKMAN, 3, Seamore Place, Park Lane, W.1.

April 21, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

FRANK IAN HAMILTON, Public Health Department, Town Hall, Johannesburg;

NORMAN SEPTIMUS SHIPWAY, New Consolidated Gold Fields, Ltd., Simmonds Street, Johannesburg;

JOHN MARSHALL SPINK, 49, The Drive, Hove, Sussex;

SAMUEL MARTIN SPINK, 43, St. Aubyn's, Hove, Sussex;

RICHARD MICHAEL TREVETHAN, Flight-Lieut. R.A.F., 128, Piccadilly, W.1.

The Meeting heartily approved that a telegram of congratulation be sent to Mr. RICHARD INWARDS on the occasion of his 86th birthday on April 22. Mr. Inwards had been a Fellow for 63 years and was therefore the senior Fellow of the Society. He was President in 1894-5 and a joint editor of the *Journal* for twenty years.

CORRESPONDENCE AND NOTES.

Meteorological Characteristics associated with the Westerly Type of Weather at Cranwell, Lincolnshire.

The following is a condensed account of a paper by Messrs. W. H. Pick and G. A. Wright dealing with the local characteristics at Cranwell of the "westerly" type of weather. The classification into types was based on an examination of the 07h (G.M.T.) synoptic charts published in the *Daily Weather Report* of the Meteorological Office, London, for the period January 1920 to October 1925. The complete paper is, by the kindness of the authors, lodged in the Society's Library, and is available for

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reference by those desiring more detailed information than it is possible to give in this short summary.

The pressure distribution is that represented by straight west to east isobars over the British Isles with areas of low pressure existing to the north.

Summary of Results.

(*a*) Winter and autumn are the seasons most favouring the occurrence of the westerly type.

(*b*) Considering 13h. the type is less cloudy than normal in spring and autumn and more cloudy than normal in winter and summer. The percentage of overcast skies (*i.e.*, skies with nine-tenths or more of cloud) at that hour is high with the type in winter and summer.

(*c*) There is a total absence of any bad or poor visibilities with the type in summer at any hour, and high percentages of good or very good visibilities during that season at all hours. Autumn is the season giving the highest percentages of bad or poor visibilities.

(*d*) At all seasons the type is markedly below the normal in fogginess.

(*e*) The type is marked by considerably lower percentages of rain days than the normal in winter and spring, by a slightly lower percentage than normal in autumn, and by a slightly higher percentage in summer.

(*f*) The type is free from snow and sleet during all seasons, almost free from hail and below the normal in thunder.

(*g*) Even in winter the type is seldom accompanied by frosts, either on the ground or in the screen, whilst in the other three seasons it is free from frost of any description.

(*h*) On the whole the type is not one of high relative humidities.

A "Willy Willy."

We are indebted to Mr. H. A. Hunt, the Australian Commonwealth Meteorologist, for some interesting details of a "Willy Willy" or hurricane which struck the north-west coast of Australia on January 22, 1926.

The storm differed from Willy Willys experienced in the past in that, instead of following the usual course and passing southward down the coast and then either passing to the Great Australian Bight or losing intensity off the west coast, it filled up *in situ*, leaving the pressure distribution in other parts of Australia not materially affected.

For the fortnight preceding the cyclone, a large high-pressure area lay over the Western Bight and a "low" was situated off the north-west coast. The distribution of pressure and wind for January 22 and the following day is shown in Figs. 1 and 2, which are reproduced from charts supplied by Mr. Hunt. On the 22nd the centre of low pressure lay to the north of Broome, where the full force of the storm was felt. By the 23rd the centre had moved inland slightly. The winds at Broome had veered from SE to SW and moderated, but the north-westerly wind on the northern side of the system showed a compensating increase.

The barograph record made at Broome during the period showed a rapid fall of pressure during the afternoon of Friday, the 22nd.

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Pressure at 10.30 a.m. was 29.391in., and from then until 6 p.m. the barometer fell steadily to 29.00in., while the lowest pressure recorded (28.980in.) was reached at 7.40 p.m.

Rainfall was exceptionally heavy. The floods at Moola Bulla were stated as being the worst for a period of forty years, ten inches of rain being measured during the week. At Broome the schooner Mina became a total wreck although anchored in the bay and held by five lines. Hardly a house, tree or structure of any kind escaped damage, the gale lasting from about 9 a.m. on the Friday until 3 a.m. on the Saturday morning. Telegraphic communication was much interrupted and repairs were delayed owing to the severe flooding of the surrounding country.

The following extract from an air pilot's report to the Western Australian Airways Limited is interesting as showing the unstable nature of the air currents following the passage of the storm:

> "At a height of 4,000ft. the air was bumpy but not exceptionally so, although I was strapped in and my passenger found the trip decidedly uncomfortable. I then noticed that the machine was rising rapidly and I pulled the throttle half-shut, but still the machine went up.
>
> "At a height of 6,000ft. the air was so terribly bumpy that I was obliged to wedge myself under the side cowling for additional support, the passenger having a very rough time and actually bumping his head severely on the cabin roof.

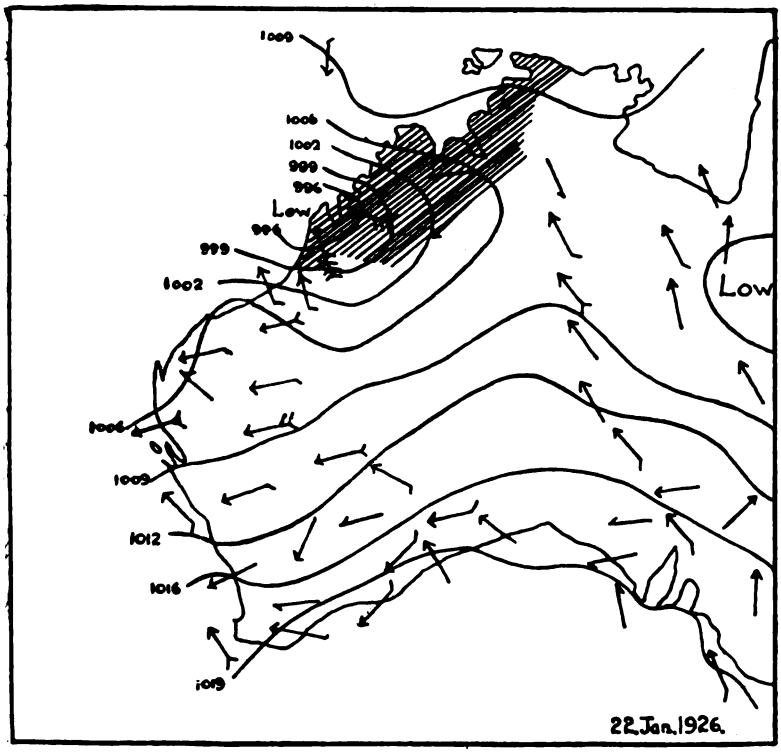

FIG. 1.—Pressure and Wind, January 22, 1926.
The wind force on the Beaufort scale is indicated by the number of flèches on the arrows (including barbs).

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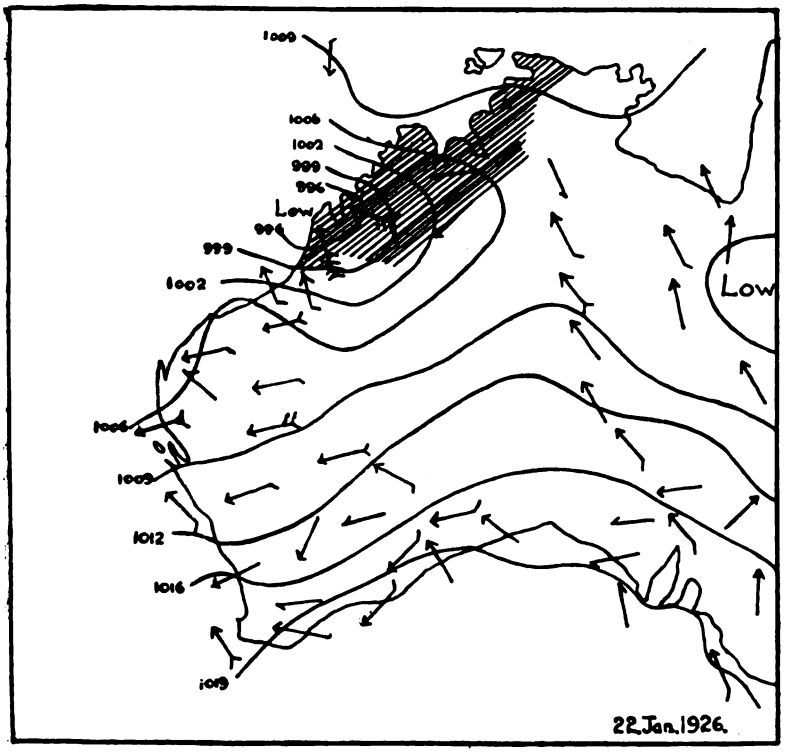

FIG. 1.—Pressure and Wind, January 22, 1926.
The wind force on the Beaufort scale is indicated by the number of flèches on the arrows (including barbs).

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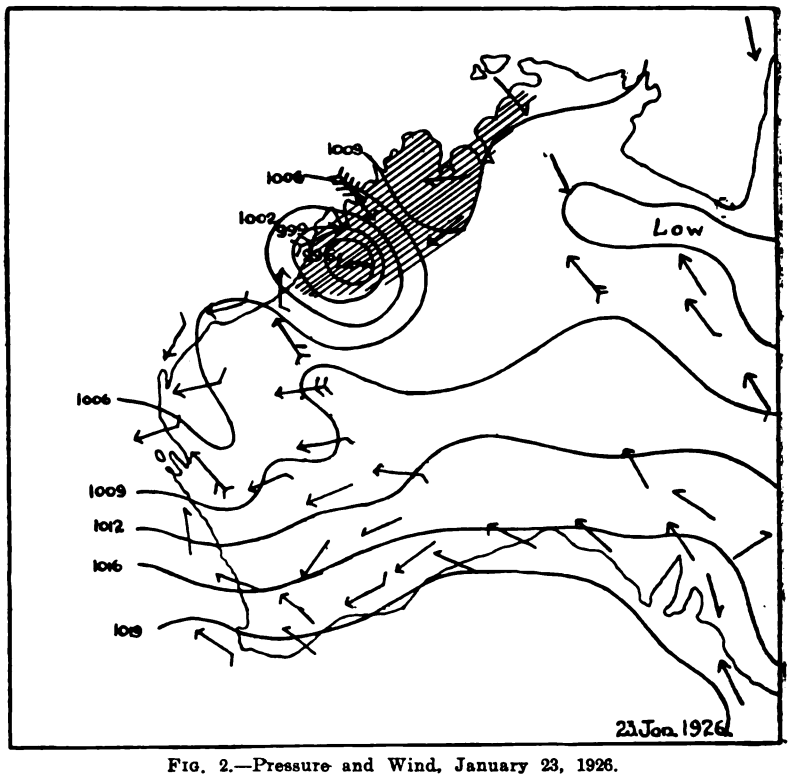

FIG. 2.—Pressure and Wind, January 23, 1926.

"In order to regain the lower altitude where the air was not so rough, I closed the throttle, but the machine hung at the higher altitude for quite an appreciable time before descending. I then continued at a height of about 4,000ft., but had little throttle opening as there was a continual tendency for the machine to gain height."

These conditions apparently persisted for some days after the storm had passed. As the general wind direction was from the east, this was probably due to extensive heating of the air in its passage over the desert regions which cover a good deal of the centre of the continent.

The Weather at Hodsock Priory.

With 1925, Mr. Mellish completed a continuous run of observations for fifty years at Hodsock Priory. It is an accomplishment of no mean order, considering that for the whole period Mr. Mellish has himself been responsible personally for the observations. He has made the publication of his customary summary of the year's weather the occasion for a review of fifty years' observations. In temperature, mean values are given for the period 1881 to 1925 for screen readings. A period of 44 years is covered by observations of earth temperature at a depth of one foot, and a period of 25 years for records of readings at a depth of four feet. The differences of the new means compared with those previously calculated for the 35 years 1881 to 1915 are, as might be

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expected, small. Particulars of extreme values both of temperature and pressure are also given, while the review of the rainfall measurements for fifty years brings out some interesting details. The year 1887 was the driest with a total of 15.95in., 1921 being the next driest with 16.65in., but in the year ended July, 1921, only 13.78in. were collected.

Useful Solar and Meteorological Data, 1924 and 1925.

The following tables, the publication of which was commenced in the October number of the *Journal* last year, contain a number of data of interest in connection with the meteorology of the globe, but which are not readily accessible to most investigators. They are here brought up to date as far as possible, data for 1924 and 1925 being available for some of the elements.

The figures for the mean values of the solar constant are taken from the *Smithsonian Miscellaneous Collection*, Vol. 77, No. 3. They represent the means obtained from observations at Harqua Hala and Montezuma.

The magnetic figures have been extracted from the "Caractère Magnetique" published by the Royal Meteorological Institute of the Netherlands,

The sunspot figures are extracted from *Astronomische Nachrichten;* a relative number of 100 corresponds with about one five-hundredth of the sun's visible disc covered by spots, including both umbra and penumbra.

TABLE II.—DAILY VALUES OF THE MAGNETIC CHARACTER, 1924.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	*0.0*	0.3	*0.0*	0.1	0.3	0.2	0.3	0.5	**1.4**	0.1	**1.0**	0.0
2	0.2	0.3	0.8	0.0	0.1	0.1	0.4	0.4	*0.1*	0.1	0.7	0.1
3	1.2	0.5	1.0	0.7	0.2	*0.0*	*0.0*	0.4	0.4	0.1	0.6	0.2
4	0.3	0.2	0.4	*0.1*	0.2	0.3	*0.1*	0.8	0.8	1.0	0.2	0.2
5	0.2	**1.5**	0.7	*0.1*	0.2	0.2	0.1	**1.0**	0.9	0.5	*0.0*	*0.0*
6	0.2	**1.0**	0.9	**1.1**	*0.0*	*0.0*	0.6	0.8	1.0	0.4	0.9	*0.0*
7	0.6	0.8	**1.3**	**1.0**	*0.0*	*0.1*	0.8	0.5	**1.7**	0.9	0.3	0.6
8	0.6	0.2	**1.1**	0.3	0.3	*0.1*	0.2	0.4	**1.7**	0.6	*0.0*	0.6
9	0.4	0.1	1.0	0.2	0.4	1.0	**1.5**	0.1	0.9	0.2	0.9	0.3
10	**1.6**	0.8	0.7	0.1	0.1	**2.0**	0.9	0.1	0.8	0.1	0.7	0.2
11	0.8	0.7	0.5	*0.0*	0.3	**1.9**	0.6	*0.1*	*0.1*	*0.1*	0.2	0.6
12	*0.2*	0.1	0.5	0.2	0.9	0.8	0.2	*0.0*	1.1	*0.0*	0.3	**1.4**
13	*0.0*	0.2	0.1	*0.0*	0.5	0.6	0.4	0.2	0.8	0.1	**1.0**	**0.7**
14	*0.0*	*0.0*	*0.1*	0.2	*0.0*	*0.1*	0.1	0.1	0.2	*0.0*	0.6	0.3
15	0.6	*0.0*	*0.1*	0.5	0.1	0.6	1.0	0.1	0.6	0.6	0.5	0.6
16	0.8	0.8	0.5	0.2	0.8	0.8	0.6	0.3	*0.1*	0.9	0.1	*0.0*
17	0.6	0.6	*0.0*	**0.7**	0.4	0.4	0.6	**1.2**	*0.2*	0.5	*0.1*	0.6
18	0.2	*0.0*	0.5	0.6	*0.0*	**1.5**	0.8	**1.2**	0.4	**1.1**	*0.0*	0.5
19	0.5	0.3	0.9	0.5	0.2	**1.6**	0.7	0.4	0.5	0.1	**1.6**	0.6
20	*0.0*	**1.7**	**1.0**	0.4	0.4	**1.2**	**1.0**	*0.0*	*0.1*	0.5	0.3	**1.2**
21	0.2	**1.2**	1.0	0.6	**1.8**	0.9	1.0	*0.0*	0.3	0.7	0.6	**1.2**
22	**1.3**	1.0	1.0	0.4	**2.0**	0.9	0.3	0.2	0.4	0.4	0.1	0.4
23	**1.6**	**1.2**	0.9	0.3	**1.7**	0.9	*0.0*	0.3	1.1	**1.8**	0.1	**0.8**
24	1.1	0.8	0.3	0.4	**1.0**	0.4	0.0	0.1	**1.4**	**1.9**	**1.9**	0.4
25	0.8	0.8	0.4	**1.2**	0.8	0.4	**1.0**	*0.0*	0.6	**1.1**	0.6	0.0
26	0.9	0.8	0.2	**1.2**	0.4	0.3	**1.3**	0.2	0.4	0.2	**1.0**	0.1
27	0.3	0.3	0.3	0.5	0.6	0.4	**1.4**	0.1	**1.2**	**1.0**	0.4	0.2
28	0.3	*0.0*	*0.1*	0.4	**1.4**	0.3	0.7	0.2	0.8	0.4	0.9	0.1
29	**2.0**	*0.0*	0.8	0.6	0.7	0.4	0.2	**1.2**	0.3	*0.0*	0.5	*0.0*
30	**1.8**	...	**1.7**	*0.1*	0.6	0.7	*0.0*	**1.1**	0.2	*0.0*	*0.1*	*0.0*
31	0.6	...	**1.0**	...	*0.1*	...	*0.0*	0.7	...	0.8	...	0.4

NOTE.—Calm days are printed in italics; disturbed days in heavy type.

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TABLE II., *continued.*— DAILY VALUES OF THE MAGNETIC CHARACTER, 1925.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.1	0.7	**0.9**	0.7	0.1	0.9	0.7	0.5	**1.6**	0.8	**1.3**	0.5
2	0.1	0 1	0.1	0.8	*0.0*	0.9	0.5	0.2	1.6	*0.3*	**1.1**	0.4
3	0.5	*0.0*	*0.1*	**1.1**	0.4	1.0	0.4	1.0	1.0	*0.1*	0.2	*0.1*
4	*0.0*	*0.0*	0.4	*0.1*	**1.8**	0.8	0.2	0.9	0.8	1.1	0.1	0.4
5	0.7	0.1	**0.9**	0.9	**1.0**	0.5	0.5	0.3	0.7	0.9	*0.0*	0.9
6	0.0	0.3	0.4	0.7	0.3	1.0	0.3	0.6	0 5	0.7	0.2	**1.4**
7	0.2	0.5	0.1	0.7	0.4	0.3	0.1	**1.3**	1.1	0.4	0.2	**0.9**
8	0.1	**1.0**	*0.1*	0.6	0.6	*0.2*	0.2	**1.3**	0.2	1.2	1.1	0.4
9	0.2	**1.5**	**1.5**	**1.0**	0.8	*0.1*	0.9	0.9	0.5	**1.6**	**1.7**	0.5
10	*0.0*	0.3	**1.0**	**1.1**	0.1	0.3	1.0	0.6	*0.0*	1.0	**1.5**	0.6
11	*0.0*	0.2	0.4	0.8	0.0	0.5	0.6	*0.1*	*0.0*	1.1	1.1	0.5
12	0.1	0.6	0.2	0.9	*0.0*	0.3	0.1	*0.0*	*0.0*	**1.5**	0.4	0.2
13	1.0	0.5	0.1	0.1	0.1	**1.9**	*0.1*	*0.0*	0.1	0.9	0.9	0.5
14	0.1	0.4	0.1	0.1	*0.0*	0.8	0.7	0.3	**1.7**	0.7	**1.4**	*0.1*
15	0.1	0.1	**1.4**	**1.0**	*0.0*	0.5	**1.3**	*0.1*	**1.8**	0.9	0.7	0.9
16	**1.5**	0.6	0.4	0.6	*0.0*	0.9	*0.1*	0.3	1.1	0.7	0.1	0.6
17	**1.4**	0.7	0.2	*0.1*	0.1	0.9	*0.0*	0.8	0.9	0.4	0.1	*0.0*
18	1.0	0.3	*0.0*	0.1	0.8	0.6	*0.1*	**1.1**	0.5	*0.0*	0.1	**1.0**
19	**1.8**	0.7	0.3	*0.0*	0 8	*0.2*	0.4	**0.8**	0.2	0.3	0 1	0.3
20	**1.3**	0.7	0.8	**1.1**	0.1	*0.0*	*0.1*	0.3	0.2	0.8	0.3	0.7
21	0.9	*0.0*	0.2	0.3	0.1	*0.0*	0.9	0.3	**1.9**	**1.7**	*0.0*	*0.0*
22	0.2	*0.0*	0.3	0.2	0.4	0.3	**1.0**	**1.5**	1.1	1.5	*0.1*	0.1
23	**1.1**	*0.0*	**0.6**	0.2	0.2	**1.3**	0.7	**1.8**	0.8	**1.9**	0.2	0.6
24	0.9	**0.7**	0.5	*0.1*	0.5	**1.9**	0.4	0.6	**1.8**	**1.8**	0.9	0.8
25	*0.0*	**0.8**	0.1	*0.0*	0.4	**1.3**	0.9	0.7	0.6	0.7	0.5	0.4
26	0.1	0.1	0.5	0.4	0.5	0.5	**1.7**	0.5	0.5	0.4	0.1	*0.0*
27	0.1	0.0	0.9	0.7	0.8	1.2	**1.4**	0.1	0.1	0.9	*0.0*	**1.5**
28	*0.0*	**0.8**	*0.0*	0.3	**1.3**	**1.3**	**1.1**	*0.0*	0.1	0.2	*0.0*	**1.7**
29	0.1	—	0.5	0.5	0.5	0.8	0.4	0.4	*0.0*	*0.0*	0.0	0.5
30	0.3	—	0.1	0.2	**1.4**	0.8	0.0	0.9	*0.0*	*0.0*	0.0	0.6
31	0.0	—	*0.1*	—	**1 3**	—	0.1	0.6	—	0.9	—	0.5

TABLE III.—DAILY RELATIVE SUNSPOT NUMBERS, 1924.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	0	15	0	0	29	26	25	42	27	11	0
2	0	0	11	0	0	46	34	30	37	45	7	0
3	0	0	7	0	0	47	32	38	59	36	0	13
4	8	0	7	0	0	44	31	31	37	42	0	0
5	7	0	0	0	0	48	35	29	40	38	0	0
6	0	0	0	11	7	62	36	28	30	36	0	0
7	0	0	0	0	11	42	39	14	17	45	0	8
8	0	0	0	0	19	28	47	13	17	41	0	8
9	0	0	0	0	14	23	52	23	7	38	0	16
10	0	0	0	0	15	14	55	7	14	28	0	25
11	0	0	0	0	22	18	55	8	18	24	12	22
12	0	0	0	0	32	8	55	14	31	23	14	30
13	0	0	0	0	31	25	40	16	28	20	13	26
14	0	13	0	8	43	32	46	12	22	29	15	26
15	0	12	0	0	50	29	34	8	14	20	17	25
16	0	0	0	0	47	19	29	14	13	20	36	23
17	0	0	0	9	41	18	16	15	9	17	25	20
18	0	0	0	33	45	17	7	15	14	22	41	29
19	0	0	0	40	31	16	7	14	17	15	43	28
20	0	0	0	43	25	16	0	14	19	11	38	20
21	0	0	0	42	23	22	14	17	24	16	70	34
22	0	0	8	43	28	13	23	10	22	18	50	48
23	0	0	8	34	23	12	23	11	22	17	51	38
24	0	0	0	28	24	7	12	9	31	13	53	37
25	0	28	0	28	12	16	9	9	20	29	54	18
26	0	32	0	14	13	14	19	12	17	29	46	10
27	0	21	0	7	16	17	20	11	14	21	33	0
28	0	22	0	0	17	11	25	19	41	22	23	0
29	0	19	0	0	14	13	11	36	43	24	13	7
30	0	—	0	0	11	14	16	56	35	16	10	0
31	0	—	0	—	30	—	24	41	—	12	—	0

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		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
THE SOLAR CONSTANT (in Gram-Calories per cm² per min.).														
1st Decade	1924	1.928	1.919	1.927	1.917	1.920	1.922	1.922	1.926	1.916	1.930	1.927	...	...
2nd Decade		27	15	14	13	21	21	24	18	20	31	35	...	...
3rd Decade		27	24	12	18	24	25	19	15	24	31	32	...	...
Mean for Month		1 927	1.919	1.918	1.916	1.922	1.923	1.922	1.919	1.920	1.931	1.931	...	...
MAGNETIC CHARACTER	1924	0.64	0.56	0.64	0.43	0.54	0.64	0.55	0.41	0.67	0.52	0.54	0 40	...
,, ,, ...	1925	0.66	0.60	0.65	0.44	0.55	0.65	0.56	0.42	0.69	0.53	0.55	0.41	...
SUNSPOTS (Relative Number)	1924	0.5	5.1	1.8	11.3	20.8	24.0	28.1	19.3	25.1	25.6	22.5	16.5	...
ICE-COVERED AREA (deviation from normal. Unit 1,000 sq. miles).														
Kara Sea	1924	...	...	...	0	0	+1	−5	−31	...	...	...	...	...
,, ,, ...	1925	...	...	...	0	0	+1	−3	−26	...	...	...	...	...
Barents Sea	1924	...	...	...	−25	−73	−62	−57	−48	...	...	...	...	...
,, ,, ...	1925	...	...	...	−71	−85	−90	−43	−44	...	...	...	...	...
Greenland Sea	1924	...	...	...	−49	−91	−52	−79	−7	...	...	...	...	...
,, ,, ...	1925	...	...	...	−132	−149	−127	−61	−42	...	...	...	...	...
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1924	0	−12	−25	−76	−147	−72	−26	−16	−11	−4	−4	−2	−395
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1925	−3	−9	−29	−70	−92	−60	−24	−16	−11	...	...	...	...
ICELAND, No. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1924	−4	+2	−8	−7	−8	−2	−5	−2	+1	0	0	0	−33
ICELAND, No. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1925	−4	−4	−8	−7	−8	+1	−5	−2	+1	0	0	0	−36
TEMPERATURE AT EQUATORIAL STATIONS (Deviation from normal) °F.														
Ocean Island	1924	−2.8	−0.3	−1.3	−0.2	−0.8	−0.8	−1.2	+0.1	+1.1	+0.1	+0.5	+0.5	−0.4
,, ,, ...	1925	+1.2	+1.1	+0.1	+1.0	+1.5	+1.3	+0.4	+0.9	+2.4	+0.3	+0.2	...	...
Colon, Panama	1924	+1.0	+0.6	+2.0	+1.0	+0.7	+0.9	+0.3	+1.0	+2.2	+1.4	+0.1	+0.7	+1.0
,, ,, ...	1925	+0.1	+0.5	+1.5	+1.4	+2.7	+1.7	+0.9	+1.9	+1.5	+1.9	+1.1	+2.5	+1.5
Sierra Leone	1924	−0.2	−2.3	+0.3	+0.7	+0.2	−1.4	−1.4	−1.8	−2.6	−1.8	−2.5	−1.8	−1.2
,, ,, ...	1925	−2.3	−0.9	−0.8	−0.1	−0.0	−0.9	−1.5	−0.7	−1.8	−1.4	−1.4	−0 5	−1.0
Entebbe	1924	+0.6	−1.0	+1.4	+0.9	+0.4	+1.0	+0.7	+0.7	−0.2	−0.3	+0.4	+0.9	+0.5
,, ...	1925	−1.8	−0.7	−1.1	+1.2	+0.4	−0.8	+0.4	+0.5	+0.9	+0.5	−0.8	−0.1	−0.1
Colombo	1924	+0.9	+1.2	0.0	0.0	−0.4	−0.6	−0.1	+0.4	−0.2	+0.4	+0.8	+0.6	+0.3
,, ...	1925	−1.7	−0.6	−1.0	−0.6	0.0	0.0	+0.2	0.0	+0.2	+0.6	+0.2	+1.2	−0.1
Batavia	1924	+1.6	+1.2	+0.9	+0.1	+0.9	+1.0	+1.7	+1.6	+1.7	−0.5	+0.2	−0.1	+0.9
Mean	1924	+0.2	−0.1	+0.5	+0.4	+0.2	0.0	0.0	+0.3	+0.3	−0.1	−0.1	+0.1	+0.1
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1924	−3.2	−5.9	−2.6	−3.6	−2.2	−5.5	−5.4	−5.3	−5.1	−7.4	−5.1	−7.8	−4.9
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1925	...	...	...	...	...	...	+0.6	+1.6	−2.5	+0.6	−0.4	−3.4	...

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TABLE II., *continued*.— DAILY VALUES OF THE MAGNETIC CHARACTER, 1925.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.1	0.7	**0.9**	0.7	0.1	0.9	0.7	0.5	**1.6**	0.8	**1.3**	0.5
2	0.1	0 1	0.1	0.8	*0.0*	0.9	0.5	0.2	1.6	*0.3*	**1.1**	0.4
3	0.5	*0.0*	*0.1*	**1.1**	0.4	1.0	0.4	1.0	1.0	*0.1*	0.2	*0.1*
4	*0.0*	*0.0*	0.4	*0.1*	**1.8**	0.8	0.2	0.9	0.8	1.1	0.1	0.4
5	0.7	0.1	**0.9**	0.9	**1.0**	0.5	0.5	0.3	0.7	0.9	*0.0*	0.9
6	0.0	0.3	0.4	0.7	0.3	1.0	0.3	0.6	0 5	0.7	0.2	**1.4**
7	0.2	0.5	0.1	0.7	0.4	0.3	0.1	**1.3**	1.1	0.4	0.2	**0.9**
8	0.1	**1.0**	*0.1*	0.6	0.6	*0.2*	0.2	**1.3**	0.2	1.2	1.1	0.4
9	0.2	**1.5**	**1.5**	**1.0**	0.8	*0.1*	0.9	0.9	0.5	**1.6**	**1.7**	0.5
10	*0.0*	0.3	**1.0**	**1.1**	0.1	0.3	1.0	0.6	*0.0*	1.0	**1.5**	0.6
11	*0.0*	0.2	0.4	0.8	0.0	0.5	0.6	*0.1*	*0.0*	1.1	1.1	0.5
12	0.1	0.6	0.2	0.9	*0.0*	0.3	0.1	*0.0*	*0.0*	**1.5**	0.4	0.2
13	1.0	0.5	0.1	0.1	0.1	**1.9**	*0.1*	*0.0*	0.1	0.9	0.9	0.5
14	0.1	0.4	0.1	0.1	*0.0*	0.8	0.7	0.3	**1.7**	0.7	**1.4**	*0.1*
15	0.1	0.1	**1.4**	**1.0**	*0.0*	0.5	**1.3**	*0.1*	**1.8**	0.9	0.7	0.9
16	**1.5**	0.6	0.4	0.6	*0.0*	0.9	*0.1*	0.3	1.1	0.7	0.1	0.6
17	**1.4**	0.7	0.2	*0.1*	0.1	0.9	*0.0*	0.8	0.9	0.4	0.1	*0.0*
18	1.0	0.3	*0.0*	0.1	0.8	0.6	*0.1*	**1 1**	0.5	*0.0*	0.1	**1.0**
19	**1.8**	0.7	0.3	*0.0*	0 8	*0.2*	0.4	0.8	0.2	0.3	0 1	0.3
20	**1.3**	0.7	0.8	**1.1**	0.1	*0.0*	*0.1*	0.3	0.2	0.8	0.3	0.7
21	0.9	*0.0*	0.2	0.3	0.1	*0.0*	0.9	0.3	**1.9**	**1.7**	*0.0*	*0.0*
22	0.2	*0.0*	0.3	0.2	0.4	0.3	**1.0**	**1.5**	1.1	1.5	*0.1*	0.1
23	**1.1**	*0.0*	**0.6**	0.2	0.2	**1.3**	0.7	**1.8**	0.8	**1.9**	0.2	0.6
24	0.9	**0.7**	0.5	*0.1*	**0.5**	**1.9**	0.4	0.6	**1.8**	**1.8**	0.9	0.8
25	*0.0*	**0.8**	0.1	*0.0*	0.4	**1.3**	0.9	0.7	0.6	0.7	**0.5**	0.4
26	0.1	0.1	0.5	0.4	0.5	0.5	**1.7**	0.5	0.5	0.4	0.1	*0.0*
27	0.1	0.0	0.9	0.7	0.8	1.2	**1.4**	0.1	0.1	0.9	*0.0*	**1.5**
28	*0.0*	**0.8**	*0.0*	0.3	**1.3**	**1.8**	**1.1**	*0.0*	0.1	0.2	*0.0*	**1.7**
29	0.1	—	0.5	0.5	0.5	0.8	0.4	0.4	*0.0*	*0.0*	0.0	0.5
30	0.3	—	0.1	0.2	**1.4**	0.8	0.0	0.9	*0.0*	*0.0*	0.0	0.6
31	0.0	—	*0.1*	—	**1 3**	—	0.1	0.6	—	0.9	—	0.5

TABLE III.—DAILY RELATIVE SUNSPOT NUMBERS, 1924.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	0	15	0	0	29	26	25	42	27	11	0
2	0	0	11	0	0	46	34	30	37	45	7	0
3	0	0	7	0	0	47	32	38	59	36	0	13
4	8	0	7	0	0	44	31	31	37	42	0	0
5	7	0	0	0	0	48	35	29	40	38	0	0
6	0	0	0	11	7	62	36	28	30	36	0	0
7	0	0	0	0	11	42	39	14	17	45	0	8
8	0	0	0	0	19	28	47	13	17	41	0	8
9	0	0	0	0	14	23	52	23	7	38	0	16
10	0	0	0	0	15	14	55	7	14	28	0	25
11	0	0	0	0	22	18	55	8	18	24	12	22
12	0	0	0	0	32	8	55	14	31	23	14	30
13	0	0	0	0	31	25	40	16	28	20	13	26
14	0	13	0	8	43	32	46	12	22	29	15	26
15	0	12	0	0	50	29	34	8	14	20	17	25
16	0	0	0	0	47	19	29	14	13	20	36	23
17	0	0	0	9	41	18	16	15	9	17	25	20
18	0	0	0	33	45	17	7	15	14	22	41	29
19	0	0	0	40	31	16	7	14	17	15	43	28
20	0	0	0	43	25	16	0	14	19	11	38	20
21	0	0	0	42	23	22	14	17	24	16	70	34
22	0	0	8	43	28	13	23	10	22	18	50	48
23	0	0	8	34	23	12	23	11	22	17	51	38
24	0	0	0	28	24	7	12	9	31	13	53	37
25	0	28	0	28	12	16	9	9	20	29	54	18
26	0	32	0	14	13	14	19	12	17	29	46	10
27	0	21	0	7	16	17	20	11	14	21	33	0
28	0	22	0	0	17	11	25	19	41	22	23	0
29	0	19	0	0	14	13	11	36	43	24	13	7
30	0	—	0	0	11	14	16	56	35	16	10	0
31	0	—	0	—	30	—	24	41	—	12	—	0

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		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov	Dec.	Year.
THE SOLAR CONSTANT (in Gram-Calories per cm² per min.).														
1st Decade	1924	1.928	1.919	1.927	1.917	1.920	1.922	1.922	1.926	1.916	1.930	1.927	...	...
2nd Decade		27	15	14	13	21	21	24	18	20	31	35	...	...
3rd Decade		27	24	12	18	24	25	19	15	24	31	32	...	...
Mean for Month		1 927	1.919	1.918	1.916	1.922	1.923	1.922	1.919	1.920	1.931	1.931	...	...
MAGNETIC CHARACTER	1924	0.64	0.56	0.64	0.43	0.54	0.64	0.55	0.41	0.67	0.52	0.54	0 40	...
,, ,, ...	1925	0.66	0.60	0.65	0.44	0.55	0.65	0.56	0.42	0.69	0.53	0.55	0.41	...
SUNSPOTS (Relative Number)	1924	0.5	5.1	1.8	11.3	20.8	24.0	28.1	19.3	25.1	25.6	22.5	16.5	...
ICE-COVERED AREA (deviation from normal. Unit 1,000 sq. miles).														
Kara Sea	1924	...	...	...	0	0	+1	−5	−31	...	...	...	...	...
,, ,, ...	1925	...	...	...	0	0	+1	−3	−26	...	...	...	...	...
Barents Sea	1924	...	...	...	−25	−73	−62	− 57	−48	...	...	...	...	...
,, ,, ...	1925	...	...	...	−71	−85	−90	−43	−44	...	...	...	...	...
Greenland Sea	1924	...	...	...	−49	−91	−52	−79	−7	...	...	...	...	...
,, ,, ...	1925	...	...	...	−132	−149	−127	−61	−42	...	...	...	...	...
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1924	0	−12	−25	−76	−147	−72	−26	−16	−11	−4	−4	−2	−395
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1925	−3	−9	−29	−70	−92	−60	−24	−16	−11	...	...	...	...
ICELAND, No. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1924	−4	+2	−8	−7	−8	−2	−5	−2	+1	0	0	0	−33
ICELAND, No. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1925	−4	−4	−8	−7	−8	+1	−5	−2	+1	0	0	0	−36
TEMPERATURE AT EQUATORIAL STATIONS (Deviation from normal) °F.														
Ocean Island	1924	−2.8	−0.3	−1.3	−0.2	--0.8	−0.8	−1.2	+0.1	+ 1.1	+0.1	+0.5	+0.5	−0.4
,, ,, ...	1925	+1.2	+1.1	+0.1	+1.0	+1.5	+1.3	+0.4	+0.9	+2.4	+0.3	+0.2	...	...
Colon, Panama	1924	+1.0	+0.6	+2.0	+1.0	+0.7	+0.9	+0.3	+1.0	+2.2	+1.4	+0.1	+0.7	+1.0
,, ,, ...	1925	+0.1	+0.5	+1.5	+1.4	+2.7	+1.7	+0.9	+1.9	+1.5	+1.9	+1.1	+2.5	+1.5
Sierra Leone	1924	−0.2	−2.3	+0.3	+0.7	+0.2	−1.4	−1.4	−1.8	−2.6	−1.8	−2.5	−1.8	−1.2
,, ,, ...	1925	−2.3	−0.9	−0.8	−0.1	−0.0	−0.9	−1.5	−0.7	−1.8	−1.4	−1.4	−0 5	−1.0
Entebbe	1924	+0.6	−1.0	+1.4	+0.9	+0.4	+1.0	+0.7	+0.7	−0.2	−0.3	+0.4	+0.9	+0.5
,, ...	1925	−1.8	−0.7	−1.1	+1.2	+0.4	−0.8	+0.4	+0.5	+0.9	+0.5	−0.8	−0.1	−0.1
Colombo	1924	+0.9	+1.2	0.0	0.0	−0.4	−0.6	−0.1	+0.4	−0.2	+0.4	+0.8	+0.6	+0.3
,, ...	1925	−1.7	−0.6	−1.0	−0.6	0.0	0.0	+0.2	0.0	+0.2	+0.6	+0.2	+1.2	−0.1
Batavia	1924	+ 1.6	+1.2	+0.9	+0.1	+0.9	+1.0	+1.7	+1.6	+1.7	−0.5	+0.2	−0.1	+0.9
Mean	1924	+0.2	−0.1	+0.5	+0.4	+0.2	0.0	0.0	+0.3	+0.3	−0.1	−0.1	+0.1	+0.1
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1924	−3.2	−5.9	−2.6	−3.6	−2.2	−5.5	−5.4	−5.3	−5.1	−7.4	−5.1	−7.8	−4.9
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1925	...	...	...	...	...	...	+0.6	+1.6	−2.5	+0.6	−0.4	−3.4	...

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Thunderstorm, Norwich, June 17, 1926.

A very heavy thunderstorm broke over Norwich shortly after 12h. G.M.T. on June 17, 1926. The *Eastern Evening News* gives a graphic account of the storm which is supplemented by details of rainfall amounts and temperature changes noted by Mr. J. H. Willis, one of the observers for the British Rainfall Organization. Of the rainfall measured (0.58in.) half an inch was collected in five minutes, while the temperature is reported to have fallen 15.7°F.—from 67.2°F. to 51.5°F.—in twenty minutes. At 12.15 G.M.T. a terrific clap of thunder was followed by rain in such volume that the centre of the town was flooded in a couple of minutes. Much of the precipitation took the form of hail, some of the hailstones measuring half an inch across. Damage done to fruit trees was serious.

This storm was one of a series which visited East Anglia during the day. Cromer and Lowestoft both reported thunderstorms, the former measuring 20 mm. of rain and the latter 15 mm., while reports of storms of lesser intensity were received from other localities.

The pressure situation at the time was not devoid of interest. During the previous days, depressions had crossed northern England from the Atlantic, and on Wednesday, June 16, a shallow disturbance was centred over the North Sea rather close to Spurn Head. It had then been filling up slowly for some time and pressure was rising slowly over western England and Wales. By the morning of Thursday, June 17, the depression had lost its identity and a vigorous fall had set in over western

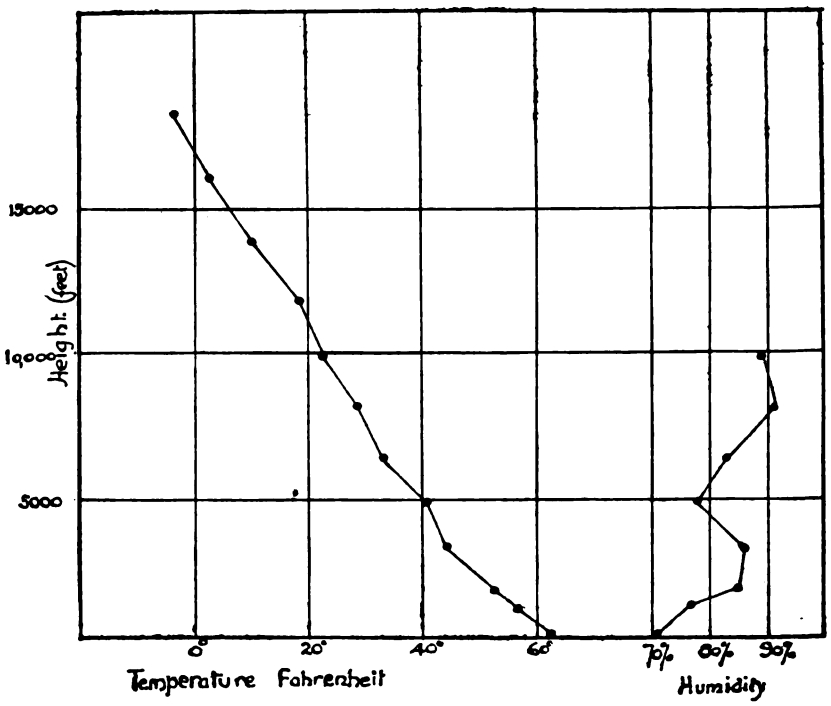

FIG. 1.—Temperature and humidity, Duxford, 10.15 h., G.M.T., June 17, 1926.

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Ireland, but although the pressure gradient had strengthened a good deal in that quarter, eastern England was still a region of light variable winds.

Fortunately, upper air temperature readings were made at Duxford twice during the day. The records for the morning ascent, together with the humidities, are shown in Fig. 1. The mean lapse rate at the morning ascent (10.15 G.M.T.) was 3.8°F. per 1,000ft. up to 18,410 ft. above mean sea level. The second ascent gave only readings up to 3,160ft., but the records up to that height showed an increase in the relative humidity, which then, between 1,700ft. and 3,160ft., rose from 85 per cent. to 93 per cent. During the morning, cumulus cloud extended upwards from 2,300ft. to nearly 10,000ft. on the whole, but in places it extended to a height of 14,000ft.

The Gordon Bennett Balloon Race.

The international free-balloon race for the second Gordon Bennett Cup took place from Antwerp on the afternoon of Sunday, May 30, 1926. The first competitor left the ground at 4.15 p.m. and was followed at

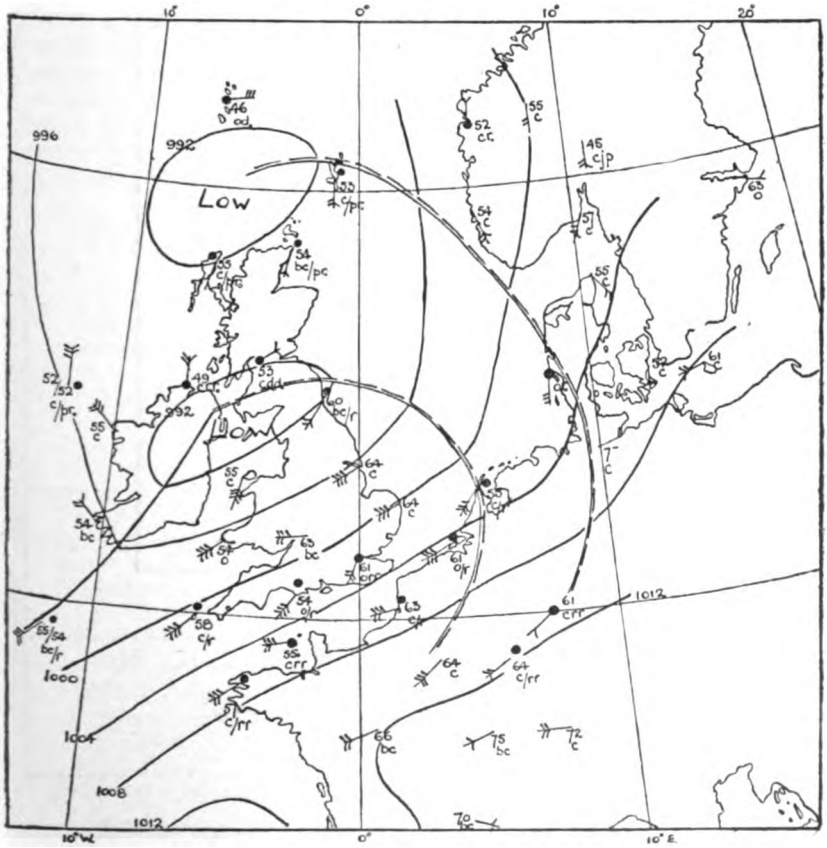

FIG. 1.—Pressure distribution May 30, 1926, 18 p. = = = occlusion, ——— cold front.

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the extent of putting it before their neighbours, he was sure there would be an increase in the number of next year's observers. It was the personal introduction which counted for so much.

One more point remained for him to mention: it was a personal one. He wished to refer to the fact that whereas Mr. Mawley had run the Phenological work for the first 21 years down to 1910, since that date it had been carried on by Mr. Clark, and this was his 15th annual report. He thought that ought to be borne in mind. The work had grown very much since Mr. Clark had taken it on, and he had given a very considerable amount of time to the Report and to the correspondence connected with it, with which he dealt himself, especially with the foreign correspondence. He felt sure the Society realized what it owed to Mr. Clark for this work, for, of course, it was a great thing to have continuity of tenure in running the series from year to year.

Mr. R. INWARDS remarked that with regard to the songs of birds, there was a book (*The Music of Nature*, by Wm. Gardiner, 8vo., 1843) which gave in musical notation the songs of many of our birds.

The PRESIDENT (Sir Gilbert Walker) said that in relation to the Brückner cycle, it would be very interesting to have any figures to indicate the general character of the past 35 years. He noticed that the previous extreme years were 1891 and 1893, separated by two years instead of seventeen as they would if the cycle were dominant.

Mr. J. E. CLARK, in reply, said he again thanked the Society for the kind way in which they received the Committee's Report. He thought some of the questions had been answered by his colleagues. As regards the year 1893, it wanted further working out, but the average of all the twelve plants was given. The other point raised by Mr. Bonacina was about the Ecological Society. He had been in communication with them, but he would try again to see if any favourable results could be obtained from collaboration. As to where the birds started from and when, he was afraid he was not an ornithologist, and although he had a great interest in the subject, he could not pretend to say very much on it. The first appearance is always a most difficult thing to decide. With regard to birds, considering that we can hardly expect all observers to discriminate between passing and stopping birds, we ask for their first appearance. If the date of one arrival did not harmonize with the date of other arrivals in the same district, it was usual to ignore it. If an observer finds he has an arrival date which by reason of its earliness is out of the usual, he will do well to look for the next arrival and see if it does not correspond more nearly to the usual date given and enter that accordingly on his form, while noting the other. The same idea applies to the plants. The observer is instructed to take some plant or group that is growing under normal conditions and to observe the first flower which opens when, but only when, other flowers on the same plant or group are also ready to open. He knew that the selection of normal specimens was most difficult, and he had lately found to his regret that one of the Committee's observers from the very beginning had continued the practice of the earlier series of observing the first seen. Besides these Preston records from 1875, the same was done in the 22 years of the Floral Calendar from 1877. Observers ought to take the observations from a plant or group which could be supposed to represent the normal characteristics of the district and not from one unduly exposed or sheltered.

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PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 17, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

FREDERICK ELMES, Cedric School, Salisbury, S. Rhodesia;
Sir RICHARD GREGORY, D.Sc., F.R.A.S., F.Inst.P., 17, Grosvenor Road, S.W.1;
WILLIAM HAYNES, 5, Alexandra Road, Reading;
WILLIAM JAMES, Middle East Headquarters, R.A.F., Villa Victoria, Cairo;
Captain W. N. McCLEAN, A.M.Inst.C.E., M.I.Mech.E., 1, Onslow Gardens, S.W.7;
ERIC MORRISON MACKAY, Sub-Lieut. R.N.R., Lingerwood, Newton Grange, Midlothian;
WILLIAM E. F. MACMILLAN, 42, Onslow Square, S.W.7;
JOHN FREDERICK MARSHALL, M.A., Seacourt, Hayling Island, Hants;
JOHN RADFORD, Sub-Lieut. R.N.R., Scalpcliffe Road, Burton-on-Trent;
JAMES B. G. ROWLAND-HILL, Homersham Road, Kingston Hill, Surrey;
PERCY JOHN SPILLETT, Homedale, Stanpit, Christchurch, Hants;
Miss JEAN MARGARET WORKMAN, 3, Seamore Place, Park Lane, W.1.

April 21, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

FRANK IAN HAMILTON, Public Health Department, Town Hall, Johannesburg;
NORMAN SEPTIMUS SHIPWAY, New Consolidated Gold Fields, Ltd., Simmonds Street, Johannesburg;
JOHN MARSHALL SPINK, 49, The Drive, Hove, Sussex;
SAMUEL MARTIN SPINK, 43, St. Aubyn's, Hove, Sussex;
RICHARD MICHAEL TREVETHAN, Flight-Lieut. R.A.F., 128, Piccadilly, W.1.

The Meeting heartily approved that a telegram of congratulation be sent to Mr. RICHARD INWARDS on the occasion of his 86th birthday on April 22. Mr. Inwards had been a Fellow for 63 years and was therefore the senior Fellow of the Society. He was President in 1894-5 and a joint editor of the *Journal* for twenty years.

CORRESPONDENCE AND NOTES.

Meteorological Characteristics associated with the Westerly Type of Weather at Cranwell, Lincolnshire.

The following is a condensed account of a paper by Messrs. W. H. Pick and G. A. Wright dealing with the local characteristics at Cranwell of the "westerly" type of weather. The classification into types was based on an examination of the 07h (G.M.T.) synoptic charts published in the *Daily Weather Report* of the Meteorological Office, London, for the period January 1920 to October 1925. The complete paper is, by the kindness of the authors, lodged in the Society's Library, and is available for

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reference by those desiring more detailed information than it is possible to give in this short summary.

The pressure distribution is that represented by straight west to east isobars over the British Isles with areas of low pressure existing to the north.

Summary of Results.

(*a*) Winter and autumn are the seasons most favouring the occurrence of the westerly type.

(*b*) Considering 13h. the type is less cloudy than normal in spring and autumn and more cloudy than normal in winter and summer. The percentage of overcast skies (*i.e.*, skies with nine-tenths or more of cloud) at that hour is high with the type in winter and summer.

(*c*) There is a total absence of any bad or poor visibilities with the type in summer at any hour, and high percentages of good or very good visibilities during that season at all hours. Autumn is the season giving the highest percentages of bad or poor visibilities.

(*d*) At all seasons the type is markedly below the normal in fogginess.

(*e*) The type is marked by considerably lower percentages of rain days than the normal in winter and spring, by a slightly lower percentage than normal in autumn, and by a slightly higher percentage in summer.

(*f*) The type is free from snow and sleet during all seasons, almost free from hail and below the normal in thunder.

(*g*) Even in winter the type is seldom accompanied by frosts, either on the ground or in the screen, whilst in the other three seasons it is free from frost of any description.

(*h*) On the whole the type is not one of high relative humidities.

A "Willy Willy."

We are indebted to Mr. H. A. Hunt, the Australian Commonwealth Meteorologist, for some interesting details of a "Willy Willy" or hurricane which struck the north-west coast of Australia on January 22, 1926.

The storm differed from Willy Willys experienced in the past in that, instead of following the usual course and passing southward down the coast and then either passing to the Great Australian Bight or losing intensity off the west coast, it filled up *in situ*, leaving the pressure distribution in other parts of Australia not materially affected.

For the fortnight preceding the cyclone, a large high-pressure area lay over the Western Bight and a "low" was situated off the north-west coast. The distribution of pressure and wind for January 22 and the following day is shown in Figs. 1 and 2, which are reproduced from charts supplied by Mr. Hunt. On the 22nd the centre of low pressure lay to the north of Broome, where the full force of the storm was felt. By the 23rd the centre had moved inland slightly. The winds at Broome had veered from SE to SW and moderated, but the north-westerly wind on the northern side of the system showed a compensating increase.

The barograph record made at Broome during the period showed a rapid fall of pressure during the afternoon of Friday, the 22nd.

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Pressure at 10.30 a.m. was 29.391in., and from then until 6 p.m. the barometer fell steadily to 29.00in., while the lowest pressure recorded (28.980in.) was reached at 7.40 p.m.

Rainfall was exceptionally heavy. The floods at Moola Bulla were stated as being the worst for a period of forty years, ten inches of rain being measured during the week. At Broome the schooner Mina became a total wreck although anchored in the bay and held by five lines. Hardly a house, tree or structure of any kind escaped damage, the gale lasting from about 9 a.m. on the Friday until 3 a.m. on the Saturday morning. Telegraphic communication was much interrupted and repairs were delayed owing to the severe flooding of the surrounding country.

The following extract from an air pilot's report to the Western Australian Airways Limited is interesting as showing the unstable nature of the air currents following the passage of the storm:

"At a height of 4,000ft. the air was bumpy but not exceptionally so, although I was strapped in and my passenger found the trip decidedly uncomfortable. I then noticed that the machine was rising rapidly and I pulled the throttle half-shut, but still the machine went up.

"At a height of 6,000ft. the air was so terribly bumpy that I was obliged to wedge myself under the side cowling for additional support, the passenger having a very rough time and actually bumping his head severely on the cabin roof.

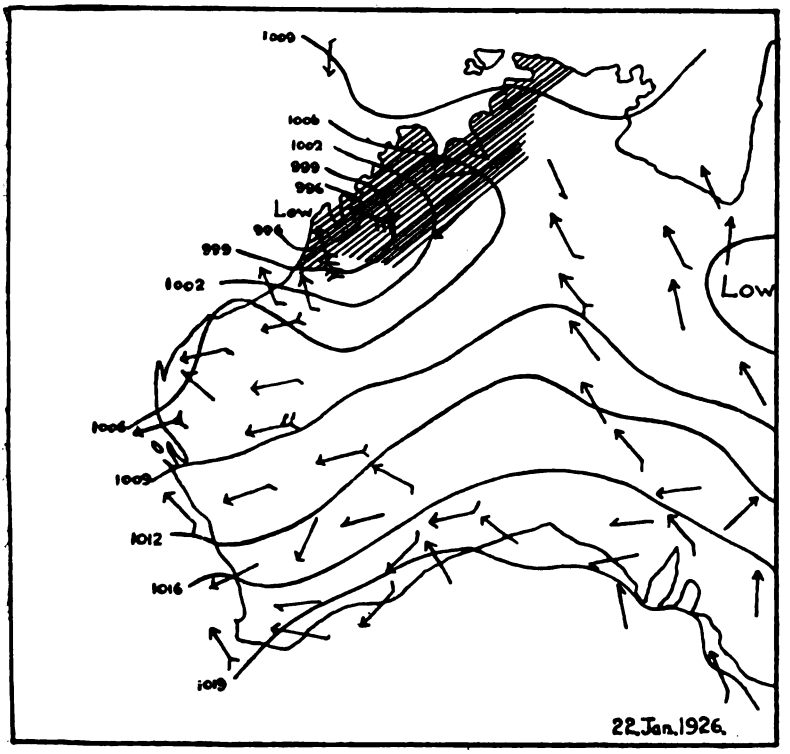

FIG. 1.—Pressure and Wind, January 22, 1926.
The wind force on the Beaufort scale is indicated by the number of flèches on the arrows (including barbs).

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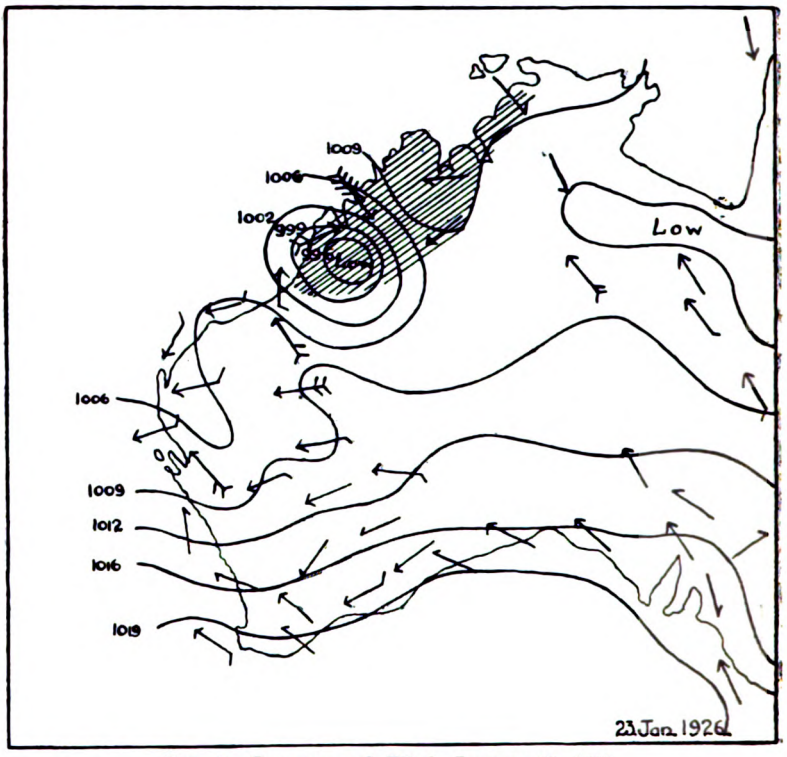

FIG. 2.—Pressure and Wind, January 23, 1926.

"In order to regain the lower altitude where the air was not so rough, I closed the throttle, but the machine hung at the higher altitude for quite an appreciable time before descending. I then continued at a height of about 4,000ft., but had little throttle opening as there was a continual tendency for the machine to gain height."

These conditions apparently persisted for some days after the storm had passed. As the general wind direction was from the east, this was probably due to extensive heating of the air in its passage over the desert regions which cover a good deal of the centre of the continent.

The Weather at Hodsock Priory.

With 1925, Mr. Mellish completed a continuous run of observations for fifty years at Hodsock Priory. It is an accomplishment of no mean order, considering that for the whole period Mr. Mellish has himself been responsible personally for the observations. He has made the publication of his customary summary of the year's weather the occasion for a review of fifty years' observations. In temperature, mean values are given for the period 1881 to 1925 for screen readings. A period of 44 years is covered by observations of earth temperature at a depth of one foot, and a period of 25 years for records of readings at a depth of four feet. The differences of the new means compared with those previously calculated for the 35 years 1881 to 1915 are, as might be

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expected, small. Particulars of extreme values both of temperature and pressure are also given, while the review of the rainfall measurements for fifty years brings out some interesting details. The year 1887 was the driest with a total of 15.95in., 1921 being the next driest with 16.65in., but in the year ended July, 1921, only 13.78in. were collected.

Useful Solar and Meteorological Data, 1924 and 1925.

The following tables, the publication of which was commenced in the October number of the *Journal* last year, contain a number of data of interest in connection with the meteorology of the globe, but which are not readily accessible to most investigators. They are here brought up to date as far as possible, data for 1924 and 1925 being available for some of the elements.

The figures for the mean values of the solar constant are taken from the *Smithsonian Miscellaneous Collection*, Vol. 77, No. 3. They represent the means obtained from observations at Harqua Hala and Montezuma.

The magnetic figures have been extracted from the "Caractère Magnetique" published by the Royal Meteorological Institute of the Netherlands,

The sunspot figures are extracted from *Astronomische Nachrichten;* a relative number of 100 corresponds with about one five-hundredth of the sun's visible disc covered by spots, including both umbra and penumbra.

TABLE II.—DAILY VALUES OF THE MAGNETIC CHARACTER, 1924.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	*0.0*	0.3	*0.0*	0.1	0.3	0.2	0.3	0.5	**1.4**	0.1	**1.0**	0.0
2	0.2	0.3	0.8	0.0	0.1	0.1	0.4	0.4	*0.1*	0.1	0.7	0.1
3	1.2	0.5	1.0	0.7	0.2	*0.0*	*0.0*	0.4	0.4	0.1	0.6	0.2
4	0.3	0.2	0.4	*0.1*	0.2	0.3	*0.1*	0.8	0.8	1.0	0.2	0.2
5	0.2	**1.5**	0.7	*0.1*	0.2	0.2	0.1	**1.0**	0.9	0.5	*0.0*	*0.0*
6	0.2	**1.0**	0.9	**1.1**	*0.0*	*0.0*	0.6	0.8	1.0	0.4	0.9	*0.0*
7	0.6	0.8	**1.3**	**1.0**	*0.0*	*0.1*	0.8	0.5	**1.7**	0.9	0.3	0.6
8	0.6	0.2	**1.1**	0.3	0.3	*0.1*	0.2	0.4	**1.7**	0.6	*0.0*	0.6
9	0.4	0.1	1.0	0.2	0.4	1.0	**1.5**	0.1	0.9	0.2	0.9	0.3
10	**1.6**	0.8	0.7	0.1	0.1	**2.0**	0.9	0.1	0.8	0.1	0.7	0.2
11	0.8	0.7	0.5	*0.0*	0.3	**1.9**	0.6	*0.1*	*0.1*	*0.1*	0.2	0.6
12	*0.2*	0.1	0.5	0.2	0.9	0.8	0.2	*0.0*	1.1	*0.0*	0.3	**1.4**
13	*0.0*	0.2	0.1	*0.0*	0.5	0.6	0.4	0.2	0.8	0.1	**1.0**	**0.7**
14	*0.0*	*0.0*	*0.1*	0.2	*0.0*	*0.1*	0.1	0.1	0.2	*0.0*	0.6	0.3
15	0.6	*0.0*	*0.1*	0.5	0.1	0.6	1.0	0.1	0.6	0.6	0.5	0.6
16	0.8	0.8	0.5	0.2	0.8	0.8	0.6	0.3	*0.1*	0.9	0.1	*0.0*
17	0.6	0.6	*0.0*	**0.7**	0.4	0.4	0.6	**1.2**	*0.2*	0.5	*0.1*	0.6
18	0.2	*0.0*	0.5	0.6	*0.0*	**1.5**	0.8	**1.2**	0.4	**1.1**	*0.0*	0.5
19	0.5	0.3	0.9	0.5	0.2	**1.6**	0.7	0.4	0.5	0.1	**1.6**	0.6
20	*0.0*	**1.7**	**1.0**	0.4	0.4	**1.2**	**1.0**	*0.0*	*0.1*	0.5	0.3	**1.2**
21	0.2	**1.2**	1.0	0.6	**1.8**	0.9	1.0	*0.0*	0.3	0.7	0.6	**1.2**
22	**1.3**	1.0	1.0	0.4	**2.0**	0.9	0.3	0.2	0.4	0.4	0.1	0.4
23	**1.6**	**1.2**	0.9	0.3	**1.7**	0.9	*0.0*	0.3	1.1	**1.8**	0.1	**0.8**
24	1.1	0.8	0.3	0.4	**1.0**	0.4	0.0	0.1	**1.4**	**1.9**	**1.9**	0.4
25	0.8	0.8	0.4	**1.2**	0.8	0.4	**1.0**	*0.0*	0.6	**1.1**	0.6	0.0
26	0.9	0.8	0.2	**1.2**	0.4	0.3	**1.3**	0.2	0.4	0.2	**1.0**	0.1
27	0.3	0.3	0.3	0.5	0.6	0.4	**1.4**	0.1	**1.2**	**1.0**	0.4	0.2
28	0.3	*0.0*	*0.1*	0.4	**1.4**	0.3	0.7	0.2	0.8	0.4	0.9	0.1
29	**2.0**	*0.0*	0.8	0.6	0.7	0.4	0.2	**1.2**	0.3	*0.0*	0.5	*0.0*
30	**1.8**	...	**1.7**	*0.1*	0.6	0.7	*0.0*	**1.1**	0.2	*0.0*	*0.1*	*0.0*
31	0.6	...	**1.0**	...	*0.1*	...	*0.0*	0.7	...	0.8	...	0.4

NOTE.—Calm days are printed in italics; disturbed days in heavy type.

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TABLE II., *continued*.— DAILY VALUES OF THE MAGNETIC CHARACTER, 1925.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.1	0.7	**0.9**	0.7	0.1	0.9	0.7	0.5	**1.6**	0.8	**1.3**	0.5
2	0.1	0.1	0.1	0.8	*0.0*	0.9	0.5	0.2	1.6	*0.3*	**1.1**	0.4
3	0.5	*0.0*	*0.1*	**1.1**	0.4	1.0	0.4	1.0	1.0	*0.1*	0.2	*0.1*
4	*0.0*	*0.0*	0.4	*0.1*	**1.8**	0.8	0.2	0.9	0.8	1.1	0.1	0.4
5	0.7	0.1	**0.9**	0.9	**1.0**	0.5	0.5	0.3	0.7	0.9	*0.0*	0.9
6	0.0	0.3	0.4	0.7	0.3	1.0	0.3	0.6	0.5	0.7	0.2	**1.4**
7	0.2	0.5	0.1	0.7	0.4	0.3	0.1	**1.3**	1.1	0.4	0.2	**0.9**
8	0.1	**1.0**	*0.1*	0.6	0.6	*0.2*	0.2	**1.3**	0.2	1.2	1.1	0.4
9	0.2	**1.5**	**1.5**	**1.0**	0.8	*0.1*	0.9	0.9	0.5	**1.6**	**1.7**	0.5
10	*0.0*	0.3	**1.0**	**1.1**	0.1	0.3	1.0	0.6	*0.0*	1.0	**1.5**	0.6
11	*0.0*	0.2	0.4	0.8	0.0	0.5	0.6	*0.1*	*0.0*	1.1	1.1	0.5
12	0.1	0.6	0.2	0.9	*0.0*	0.3	0.1	*0.0*	*0.0*	**1.5**	0.4	0.2
13	1.0	0.5	0.1	0.1	0.1	**1.9**	*0.1*	*0.0*	0.1	0.9	0.9	0.5
14	0.1	0.4	0.1	0.1	*0.0*	0.8	0.7	0.3	**1.7**	0.7	**1.4**	*0.1*
15	0.1	0.1	**1.4**	**1.0**	*0.0*	0.5	**1.3**	*0.1*	**1.8**	0.9	0.7	0.9
16	**1.5**	0.6	0.4	0.6	*0.0*	0.9	*0.1*	0.3	1.1	0.7	0.1	0.6
17	**1.4**	0.7	0.2	*0.1*	0.1	0.9	*0.0*	0.8	0.9	0.4	0.1	*0.0*
18	1.0	0.3	*0.0*	0.1	0.8	0.6	*0.1*	**1.1**	0.5	*0.0*	0.1	**1.0**
19	**1.8**	0.7	0.3	*0.0*	0.8	*0.2*	0.4	0.8	0.2	0.3	0.1	0.3
20	**1.3**	0.7	0.8	**1.1**	0.1	*0.0*	*0.1*	0.3	0.2	0.8	0.3	0.7
21	0.9	*0.0*	0.2	0.3	0.1	*0.0*	0.9	0.3	**1.9**	**1.7**	*0.0*	*0.0*
22	0.2	*0.0*	0.3	0.2	0.4	0.3	**1.0**	**1.5**	1.1	1.5	*0.1*	0.1
23	**1.1**	*0.0*	**0.6**	0.2	0.2	**1.3**	0.7	**1.8**	0.8	**1.9**	0.2	0.6
24	0.9	**0.7**	0.5	*0.1*	0.5	**1.9**	0.4	0.6	**1.8**	**1.8**	0.9	0.8
25	*0.0*	**0.8**	0.1	*0.0*	0.4	**1.3**	0.9	0.7	0.6	0.7	0.5	0.4
26	0.1	0.1	0.5	0.4	0.5	0.5	**1.7**	0.5	0.5	0.4	0.1	*0.0*
27	0.1	0.0	0.9	0.7	0.8	1.2	**1.4**	0.1	0.1	0.9	*0.0*	**1.5**
28	*0.0*	**0.8**	*0.0*	0.3	**1.3**	**1.3**	**1.1**	*0.0*	0.1	0.2	*0.0*	**1.7**
29	0.1	—	0.5	0.5	0.5	0.8	0.4	0.4	*0.0*	*0.0*	0.0	0.5
30	0.3	—	0.1	0.2	**1.4**	0.8	0.0	0.9	*0.0*	*0.0*	0.0	0.6
31	0.0	—	*0.1*	—	**1.3**	—	0.1	0.6	—	0.9	—	0.5

TABLE III.—DAILY RELATIVE SUNSPOT NUMBERS, 1924.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0	0	15	0	0	29	26	25	42	27	11	0
2	0	0	11	0	0	46	34	30	37	45	7	0
3	0	0	7	0	0	47	32	38	59	36	0	13
4	8	0	7	0	0	44	31	31	37	42	0	0
5	7	0	0	0	0	48	35	29	40	38	0	0
6	0	0	0	11	7	62	36	28	30	36	0	0
7	0	0	0	0	11	42	39	14	17	45	0	8
8	0	0	0	0	19	28	47	13	17	41	0	8
9	0	0	0	0	14	23	52	23	7	38	0	16
10	0	0	0	0	15	14	55	7	14	28	0	25
11	0	0	0	0	22	18	55	8	18	24	12	22
12	0	0	0	0	32	8	55	14	31	23	14	30
13	0	0	0	0	31	25	40	16	28	20	13	26
14	0	13	0	8	43	32	46	12	22	29	15	26
15	0	12	0	0	50	29	34	8	14	20	17	25
16	0	0	0	0	47	19	29	14	13	20	36	23
17	0	0	0	9	41	18	16	15	9	17	25	20
18	0	0	0	33	45	17	7	15	14	22	41	29
19	0	0	0	40	31	16	7	14	17	15	43	28
20	0	0	0	43	25	16	0	14	19	11	38	20
21	0	0	0	42	23	22	14	17	24	16	70	34
22	0	0	8	43	28	13	23	10	22	18	50	48
23	0	0	8	34	23	12	23	11	22	17	51	38
24	0	0	0	28	24	7	12	9	31	13	53	37
25	0	28	0	28	12	16	9	9	20	29	54	18
26	0	32	0	14	13	14	19	12	17	29	46	10
27	0	21	0	7	16	17	20	11	14	21	33	0
28	0	22	0	0	17	11	25	19	41	22	23	0
29	0	19	0	0	14	13	11	36	43	24	13	7
30	0	—	0	0	11	14	16	56	35	16	10	0
31	0	—	0	—	30	—	24	41	—	12	—	0

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		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
THE SOLAR CONSTANT (in Gram-Calories per cm² per min.).														
1st Decade	1924	1.928	1.919	1.927	1.917	1.920	1.922	1.922	1.926	1.916	1.930	1.927	...	...
2nd Decade		27	15	14	13	21	21	24	18	20	31	35	...	...
3rd Decade		27	24	12	18	24	25	19	15	24	31	32	...	...
Mean for Month		1.927	1.919	1.918	1.916	1.922	1.923	1.922	1.919	1.920	1.931	1.931	...	...
MAGNETIC CHARACTER	1924	0.64	0.56	0.64	0.43	0.54	0.64	0.55	0.41	0.67	0.52	0.54	0 40	...
,, ,, ...	1925	0.66	0.60	0.65	0.44	0.55	0.65	0.56	0.42	0.69	0.53	0.55	0.41	...
SUNSPOTS (Relative Number)	1924	0.5	5.1	1.8	11.3	20.8	24.0	28.1	19.3	25.1	25.6	22.5	16.5	...
ICE-COVERED AREA (deviation from normal. Unit 1,000 sq. miles).														
Kara Sea	1924	...	...	...	0	0	+1	−5	−31	...	...	...	...	...
,, ,, ...	1925	...	...	...	0	0	+1	−3	−26	...	...	...	...	...
Barents Sea	1924	...	...	...	−25	−73	−62	−57	−48	...	...	...	...	...
,, ,, ...	1925	...	...	...	−71	−85	−90	−43	−44	...	...	...	...	...
Greenland Sea	1924	...	...	...	−49	−91	−52	−79	−7	...	...	...	...	...
,, ,, ...	1925	...	...	...	−132	−149	−127	−61	−42	...	...	...	...	...
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1924	0	−12	−25	−76	−147	−72	−26	−16	−11	−4	−4	−2	−395
NEWFOUNDLAND BANKS (Deviation of No. of Icebergs from normal)	1925	−3	−9	−29	−70	−92	−60	−24	−16	−11	...	...	...	...
ICELAND, NO. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1924	−4	+2	−8	−7	−8	−2	−5	−2	+1	0	0	0	−33
ICELAND, NO. OF DAYS WITH ICE VISIBLE (Deviation from normal)	1925	−4	−4	−8	−7	−8	+1	−5	−2	+1	0	0	0	−36
TEMPERATURE AT EQUATORIAL STATIONS (Deviation from normal) °F.														
Ocean Island	1924	−2.8	−0.3	−1.3	−0.2	--0.8	−0.8	−1.2	+0.1	+1.1	+0.1	+0.5	+0.5	−0.4
,, ,, ...	1925	+1.2	+1.1	+0.1	+1.0	+1.5	+1.3	+0.4	+0.9	+2.4	+0.3	+0.2	...	...
Colon, Panama	1924	+1.0	+0.6	+2.0	+1.0	+0.7	+0.9	+0.3	+1.0	+2.2	+1.4	+0.1	+0.7	+1.0
,, ,, ...	1925	+0.1	+0.5	+1.5	+1.4	+2.7	+1.7	+0.9	+1.9	+1.5	+1.9	+1.1	+2.5	+1.5
Sierra Leone	1924	−0.2	−2.3	+0.3	+0.7	+0.2	−1.4	−1.4	−1.8	−2.6	−1.8	−2.5	−1.8	−1.2
,, ,, ...	1925	−2.3	−0.9	−0.8	−0.1	−0.0	−0.9	−1.5	−0.7	−1.8	−1.4	−1.4	−0 5	−1.0
Entebbe	1924	+0.6	−1.0	+1.4	+0.9	+0.4	+1.0	+0.7	+0.7	−0.2	−0.3	+0.4	+0.9	+0.5
,, ...	1925	−1.8	−0.7	−1.1	+1.2	+0.4	−0.8	+0.4	+0.5	+0.9	+0.5	−0.8	−0.1	−0.1
Colombo	1924	+0.9	+1.2	0.0	0.0	−0.4	−0.6	−0.1	+0.4	−0.2	+0.4	+0.8	+0.6	+0.3
,, ...	1925	−1.7	−0.6	−1.0	−0.6	0.0	0.0	+0.2	0.0	+0.2	+0.6	+0.2	+1.2	−0.1
Batavia	1924	+1.6	+1.2	+0.9	+0.1	+0.9	+1.0	+1.7	+1.6	+1.7	−0.5	+0.2	−0.1	+0.9
Mean	1924	+0.2	−0.1	+0.5	+0.4	+0.2	0.0	0.0	+0.3	+0.3	−0.1	−0.1	+0.1	+0.1
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1924	−3.2	−5.9	−2.6	−3.6	−2.2	−5.5	−5.4	−5.3	−5.1	−7.4	−5.1	−7.8	−4.9
VELOCITY OF SE. TRADE WIND AT ST. HELENA (Deviation from normal mi/hr.) ...	1925	...	...	...	...	...	...	+0.6	+1.6	−2.5	+0.6	−0.4	−3.4	...

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Thunderstorm, Norwich, June 17, 1926.

A very heavy thunderstorm broke over Norwich shortly after 12h. G.M.T. on June 17, 1926. The *Eastern Evening News* gives a graphic account of the storm which is supplemented by details of rainfall amounts and temperature changes noted by Mr. J. H. Willis, one of the observers for the British Rainfall Organization. Of the rainfall measured (0.58in.) half an inch was collected in five minutes, while the temperature is reported to have fallen 15.7°F.—from 67.2°F. to 51.5°F.—in twenty minutes. At 12.15 G.M.T. a terrific clap of thunder was followed by rain in such volume that the centre of the town was flooded in a couple of minutes. Much of the precipitation took the form of hail, some of the hailstones measuring half an inch across. Damage done to fruit trees was serious.

This storm was one of a series which visited East Anglia during the day. Cromer and Lowestoft both reported thunderstorms, the former measuring 20 mm. of rain and the latter 15 mm., while reports of storms of lesser intensity were received from other localities.

The pressure situation at the time was not devoid of interest. During the previous days, depressions had crossed northern England from the Atlantic, and on Wednesday, June 16, a shallow disturbance was centred over the North Sea rather close to Spurn Head. It had then been filling up slowly for some time and pressure was rising slowly over western England and Wales. By the morning of Thursday, June 17, the depression had lost its identity and a vigorous fall had set in over western

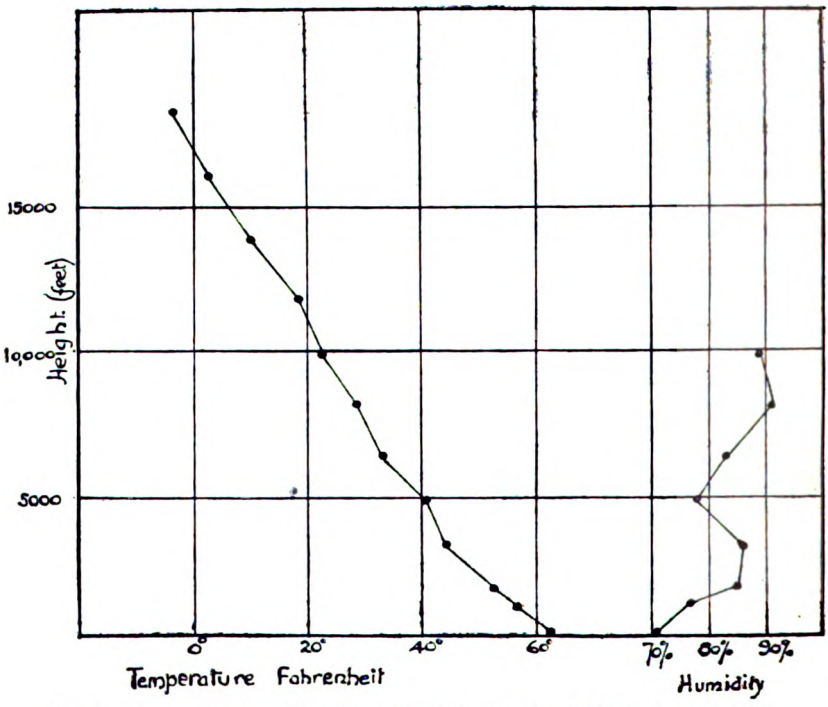

FIG. 1.—Temperature and humidity, Duxford, 10.15 h., G.M.T., June 17, 1926.

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Ireland, but although the pressure gradient had strengthened a good deal in that quarter, eastern England was still a region of light variable winds.

Fortunately, upper air temperature readings were made at Duxford twice during the day. The records for the morning ascent, together with the humidities, are shown in Fig. 1. The mean lapse rate at the morning ascent (10.15 G.M.T.) was 3.8°F. per 1,000ft. up to 18,410 ft. above mean sea level. The second ascent gave only readings up to 3,160ft., but the records up to that height showed an increase in the relative humidity, which then, between 1,700ft. and 3,160ft., rose from 85 per cent. to 93 per cent. During the morning, cumulus cloud extended upwards from 2,300ft. to nearly 10,000ft. on the whole, but in places it extended to a height of 14,000ft.

The Gordon Bennett Balloon Race.

The international free-balloon race for the second Gordon Bennett Cup took place from Antwerp on the afternoon of Sunday, May 30, 1926. The first competitor left the ground at 4.15 p.m. and was followed at

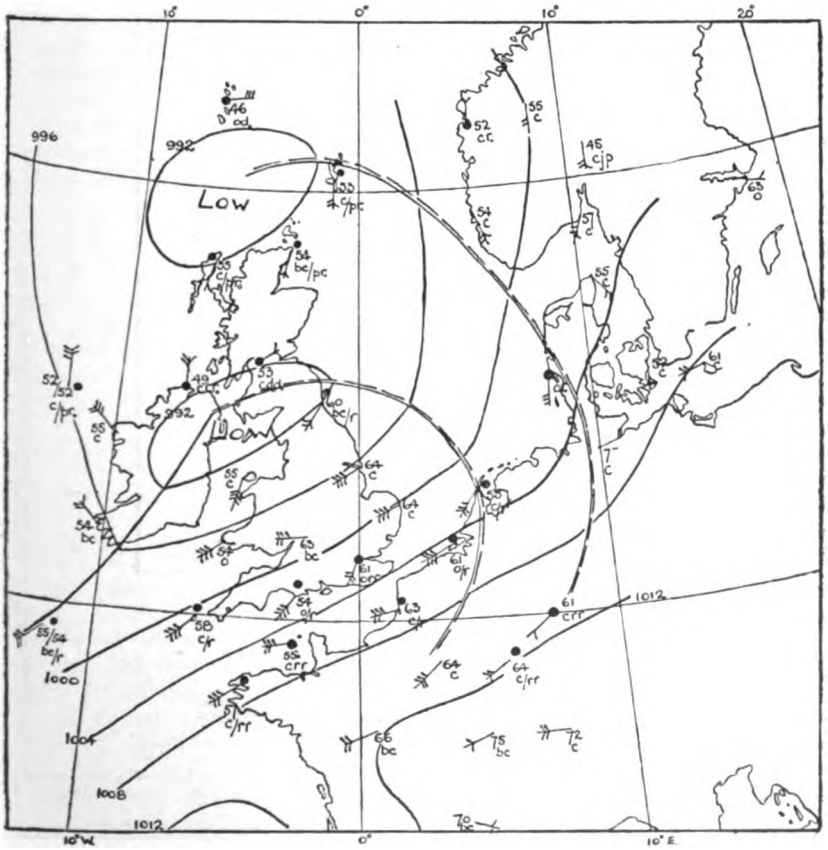

FIG. 1.—Pressure distribution May 30, 1926, 18 p. = = = occlusion, ——— cold front.

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intervals of a few minutes each by the remaining fourteen balloons, the last of which began its flight at 6.45 p.m. Two balloons—the Anjon V. and the Vieille-Tige—were placed *hors de combat* before the race owing to damage caused by the strong winds which prevailed throughout the day.

The winning balloon—the American Goodyear III.—covered a distance of 527 miles and landed at Sölvesborg in southern Sweden. An American balloon—the S.16 of the United States Army—was second, covering a distance of 372 miles, while the Belgica (Belgium) was third with a flight of 288 miles.

The weather at the time was bad. Cyclonic conditions became established during the week-end, and by Sunday two depressions constituted the principal features of the pressure distribution. The chart for

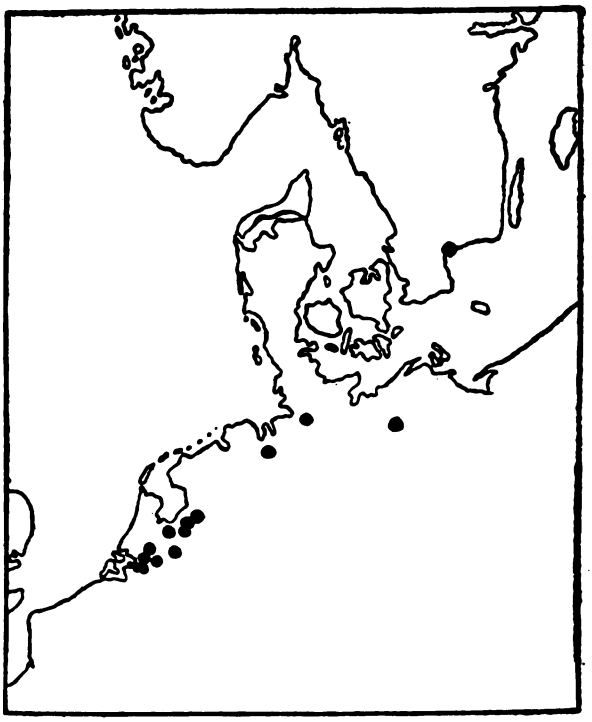

FIG. 2.—Places of fall of Balloons.

13h. of Sunday is shown in Fig. 1. The former of the two depressions was centred to the south of Thorsharn. It was occluded, the line of occlusion[1]—shown on the map as a stroked-dotted line—running in a south-easterly direction first towards Denmark and then curving through south to south-west across Germany to eastern France. The second disturbance was centred further south over southern Scotland. It was also occluded, but the situation here was further complicated by a well-

[1] See note page 342.

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marked cold front which ran from north-east Ireland in a south-westerly direction, passing to the east of Valencia and finally becoming indefinite over the Atlantic.

Between the occlusion of the second depression and its secondary cold front there existed a strong south-westerly current into which all the balloons were liberated. Owing to the unsettled nature of the weather and low-lying cloud, little definite information is available as to the strength of the upper winds, but it is probable that at 2,000ft. the speed averaged about 35 to 40 m.p.h. Rain was not continuous, being more of the intermittent or showery type, and this handicapped the competitors to an unequal degree. While some left the ground in heavy rain and were thus weighed down, others were more fortunate and were able to take advantage of the drier intervals. Very little change in the situation had occurred by 18h. The various fronts showed little movement either at their northern or southern extremities, but a movement of the central portions eastwards resulted in a bulging forwards of the cold front towards eastern England, and, of the occlusion of the second depression, towards the Danish coast, while by 7 a.m., beyond a movement eastwards of the depression to the North Sea, the situation continued unaltered.

The homogeneous character of the south-westerly current is well shown by Fig. 2, which gives the places of fall of the fifteen competing balloons. Only one, the S.16, which came down at Krakau (Mecklenburg) diverged to any extent from the average path, although some two hours or more elapsed between the starting of the first and last balloons. The table below gives the time of start, the length of the flight, and as far as possible the time of descent of each of the balloons.

TABLE I.—Duration and Distances Covered by the Competing Balloons.

Balloon.	Nationality.	Time of start.	Time of descent.	Distance covered (miles).
Goodyear III.	U.S.A.	16.53	Mon. morn.	527
S.16	U.S.A.	17.50	?	372
Belgica	Belg.	17.24	23.00	288
Pr. Leopold	Belg.	16.35	23.00	210
Miramar	Gt. Brit.	18.00	Sun. eve.	102
Penorando	Spain	16.40	20.20	93
Helvetia	Switz.	17.11	19.55	80
Picardie	France	17.07	—	62
Banshee III.	Gt. Brit.	18.45	20.15	50
Bee	Gt. Brit.	17.38	19.00	47
Aereostière I.	Belg.	18.09	—	40
Aereostière III.	Ital.	16.30	—	22
Campino III.	Ital.	17.19	—	18
Campino IV.	Ital.	18.07	—	16
Akron N.A.A.		18.28	—	?

The American balloons carried wireless installations for the reception of radio telephony weather reports, and it is hoped that, in future, organized reports will be issued specially for the race. Next year the race will be held in America, and no doubt the Americans will organize a system of reports such as they always do in connection with their National Elimination Races.

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A Note on Dr. Jeffreys's Theory of Atmospheric Circulation.

The problem of the general circulation of the atmosphere is of such importance and the solution is so long overdue that any contribution towards it deserves full consideration. It is for this reason that I should like to be allowed to make some comments on Dr. Jeffreys's paper published in the January number of the *Journal*.

In the first place I think that the somewhat mystic argument of paragraph 3.2 of Dr. Jeffreys's paper can be made more intelligible by examining what the mathematical procedure implies.

Suppose that pressure and temperature are distributed symmetrically and that the gradients of pressure and temperature are increasing slowly, everywhere in the same proportion. The winds are very nearly geostrophic but not quite; there must be small currents from low pressure to high to provide for the increasing anomaly of pressure. [The analogy of water rotating in a tumbler illustrates the movement from *low* pressure to *high* when the general activity is increasing.] These small currents bear to the right and so increase the winds along the parallels of latitude. To preserve the balance this increase must suffice to keep the winds along the parallels up to geostrophic strength. The problem which Dr. Jeffreys set himself in writing down equation 3.2 (2) was to find what distribution of pressure would respond to changes of temperature in this way. His solution applies only to the case of an atmosphere free from friction. Even for that case he does not demonstrate that the circulation is stable. It is interesting, however, to have the solution of the problem. Dr. Jeffreys mentions one important characteristic of the solution, the gradient for east winds at the surface in all latitudes. It is worth noting in addition that the integrated pressure falls off steadily from equator to poles, so that there are west winds aloft and in every latitude the circulation is, on the whole, from west to east. Moreover, the angular momentum of the currents about the earth's axis is neatly provided for by the displacement of the air from the fast-moving equatorial regions towards the poles.[1]

As Dr. Jeffreys mentions, the solution of this problem does not provide the explanation of the actual circulation, which must be largely governed by friction. On the earth, even on an ideal symmetrical earth, friction necessitates a balance between east and west winds at the surface. Now the most conspicuous features of the actual circulation are the east winds of the trade wind zones and the west winds of middle latitudes. These are separated by the anticyclonic belts of the horse latitudes. That these anticyclonic belts are not due to the distribution of land and water is shown by the fact that they persist over the land and are responsible for the great desert areas of both hemispheres.

The popular theory of the trade winds is obviously inadequate. If the trade winds merely represented the drift of air from the cooler parts of the globe to the warmer, they would be developed in middle latitudes rather than in the tropics. There must be some cause other than mere

[1] This follows from the identity

$$\int_0^{\frac{1}{2}\pi} \frac{1}{2\omega\cos\theta}\,\frac{1}{a}\frac{\partial P}{\partial\theta}\,.\,a\sin\theta\,.\,2\pi a^2\sin\theta\,d\theta = -\omega\int_0^{\frac{1}{2}\pi}\frac{p'}{g}a^2\sin^2\theta\,.\,2\pi a^2\sin\theta\,d\theta$$

which can be deduced from the equation 3.2 (4) in the paper by using 2 (15) and 3.2 (3).

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convection to force air into the anticyclonic belt. To my mind, the most probable explanation is that in middle latitudes the upper winds, which are strong west winds, speed up the air at lower levels, dragging it onwards by turbulence on a large scale. This air is flung outwards and piled up in the anticyclonic belts. According to this theory, the chain of cause and effect is—temperature distribution, pressure gradient in the upper atmosphere, strong west winds aloft, induced west winds below, anticyclonic belts, trade winds. The details of the mechanism are not clear, however, and one looks to see how Dr. Jeffreys handles them.

From the concluding section of his paper it would appear that he had found the key to the riddle. He writes: "Taking into account, however, the observational fact that surface winds do exist, it has been proved by pure dynamical theory that the only possible motion consists of westerly circulations around the poles with a corresponding easterly circulation in middle latitudes or near the equator . . . and with a system of cyclones closely similar to those we know." Turning to the argument to which this statement refers, we find, however, that it is hardly "pure dynamical theory." The argument is on page 99 of the paper: "But we notice that in the northern hemisphere, for instance, air moving northwards cannot proceed far without acquiring a velocity from the west, and air moving southwards acquires a velocity from the east. Considering any interchange of air across a parallel of latitude, then uv must be negative both for the air moving north and for that moving south." The statement is presumably a paraphrase for the law that a particle moving on a level surface in the absence of horizontal forces bears to the right in the northern hemisphere. With the same justification we could say that air moving eastwards could not proceed far without acquiring a velocity from the north and air moving westwards would acquire a velocity from the south and deduce that uv must always be positive. Actually in the case of a swarm of particles moving independently over the globe velocities from SE and NE would be equally common, and so would velocities from SW and NW. It is not obvious that any general statement with regard to the movement of the atmosphere can be derived from this result. As far as I can see, the "pure dynamical theory" breaks down. It is surely very unlikely that any theory of atmospheric circulation can succeed which ignores the fact that it is hotter at the equator than at the poles.

By the development of the conceptions of integrated pressure and total flow, Dr. Jeffreys has provided useful machinery for the discussion of the general circulation. It is to be hoped that by the help of this machinery and of modern ideas of turbulence the theories of Ferrel and Oberbeck will be revised and a consistent explanation of the actual circulation will be evolved.

Finally, it may be mentioned as a detail of some interest that the h which plays an important part in Dr. Jeffreys's paper and corresponds to the depth of the ocean in the analogous tidal theory is the height above ground of the centre of gravity of a column of the atmosphere. This is easily proved from the definitions on pages 86, 87, 88, for

$$P = \int_0^\infty p\, dz = \left[pz \right]_0^\infty - \int_0^\infty z \frac{dp}{dz} dz = \int_0^\infty g\rho z\, dz$$

$$p_0 = \int_0^\infty g\, \rho\, dz \quad \text{and} \quad h = P/p_0$$

F. J. W. WHIPPLE.

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Weather Notes in Swift's Journal to Stella.

Swift's Journal to Stella extends from September 2, 1710, to June 6, 1713. There are 215 references to the weather, which makes an average of 78 days a year; this is rather better than Pepys,[1] who gives references for the period covered by his diary on 62 days per year. There is nothing of very great note in the Journal; the winters on the whole were open, the only real period of cold seems to have been from January 19 to February 9, 1711. On March 23, 1712, Swift saw fifty flashes of lightning in the evening, an early date for a thunderstorm not of the line squall type. There seems to have been a drought for some time prior to June 17, 1712. The first three months of the year 1713 were very rainy.

In the notes that follow the year is given as beginning on January 1. It must be remembered that the old style was still used, so that January 1, for instance, corresponds to January 12 new style; the dates in this paper are those given in the Journal, *i.e.*, old style.

The notes refer to London, Chelsea, or Kensington, except where Windsor is indicated in square brackets. Swift went to Chelsea on April 26, 1711, and returned on July 5. "Our town" during this period refers to Chelsea.

Swift's memory for past weather is not accurate; he complains of the hot weather at the beginning of June, 1711, and under dates June 30, July 6 and July 17, he says that there was no hot weather in June. His description of hot weather should be usually taken as somewhat exaggerated, as hot weather affected him greatly. "Twelve-penny weather" seems to mean rainy weather.

Presto is one of the names Swift gives himself in writing to Stella. It is somewhat amusing to find that the weather is frequently given as the excuse for Swift to remain all day at the house of Mrs. Vanhomrigh, at the time when he was commencing his ill-fated acquaintance with her daughter Esther (Vanessa).

C. J. P. Cave.

Quotations on the Weather from Swift's Journal to Stella.

1710.

Sept. 23. We have had a fortnight of the most glorious weather on earth, and still continues.

26. Last Sunday, Sept. 24, 1710, was as hot as Midsummer.

27. This is the first rainy day since I came to town.

Oct. 2. We left Hampton Court at Sunset, and got here in a chariot and two horses time enough by starlight.

3. Remember that yesterday, Oct. 2, was a cruel hard frost, with ice; and six days ago I was dying with heat.

26. No, we have had none of your snow, but a little one morning; yet I think it was great snow for an hour or so, but no longer. . . . It is plaguey twelve-penny weather this last week, and has cost me ten shillings in coach and chair hire.

31. This month ends with a fine day.

Nov. 9. It is mighty warm; yet I fear I shall catch cold this wet weather.

13. I must only add that after a long fit of rainy weather, it has been fair two or three days, and is this day grown cold and frosty; so that you must give poor little Presto leave to have a fire in his chamber morning and evening too, and he will do as much for you.

[1] See *Q.J.R. Meteor. Soc.*, **46**, 1920, pp. 65 *et seq.*

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Dec. 5. We have had the devil and all of rain by the by.
6. It is such monstrous rainy weather that there is no doing with it.
9. It is, however, such abominable weather, that no creature can walk.
10. Delicate weather begun only to-day. A terrible storm last night: we hear one of your packet boats is cast away.
11. I do not like this open weather. . . . It has rained all this evening like wildfire.
13. It is a rainy ugly day. . . . [evening] it was the rainiest day that ever dripped.
17. I walked all the way home from Hatton Garden at six, by moonlight, a delicate night.
26. The rain caught me . . . drove to the coffee house, where the rain kept me till nine.
27. Did you ever see so open a winter in England? We have not had two frosty days; but it pays it off in rain: we have not had three fair days these six weeks.
30. The weather grows cold, you sauceboxes.

1711.

Jan. 1. Faith it is cold. . . . [in answer to a letter from Stella] Wind—we saw no wind here, nothing at all extraordinary at any time. We had it once when you had it not. . . . Your chimney fell down. God preserve you. I suppose you only mean a brick or two: but that is a damned lie of your chimney being carried to the next house with the wind. Do not put such things upon us; these matters will not pass here; keep a little to possibilities. . . . No, did I not tell you but just now, we have no high winds here?
6. It is very cold this morning in bed.
14. It is spring with us already, I ate asparagus the other day. Did you ever see such a frostless winter?
16. I keep very good fires, though the weather be warm.
19. This was an insipid snowy day.
20. We had a great deal of snow to-day, and it is terrible cold.
21. It has snowed terribly all night, and is vengeance cold. I am not yet up, but cannot write long, my hands will freeze. . . . At night. We are now here in high frost, the largest fire can hardly keep us warm. It is very ugly walking.
22. Morning: Starving, starving, uth, uth, uth, uth, uth. Do you not remember I used to come into your chamber, and turn Stella out of her chair, and rake up the fire in a cold morning, and cry uth, uth, uth? &c. O faith, I must rise, my hand is so cold I can write no more. . . . I chose to walk there [to the City] for exercise in the frost. But the weather had given a little, as you women call it, so it was something slobbery.
23. Morning. They tell me it freezes again, but it is not so cold as yesterday. . . . It was such a terrible day I could not stir out till one.
31. We are here in as smart a frost for the time as I have seen; delicate walking weather, and the Canal and Rosamond's pond full of the rabble sliding, and with skates, if you know what those are. Patrick's bird's water freezes in the gallipot, and my hands in bed.

Feb. 1. I walked plaguey carefully, for fear of sliding against my will.
4. Our frost holds like a dragon.
5. It is still terribly cold.
6. All the frost is gone. It thawed on Sunday [Feb. 6], and so continues, yet ice is still on the Canal (I did not mean that of Laracor, but St. James's Park) and boys sliding on it.

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7. We have a monstrous deal of snow, and it has cost me two shillings to-day in chair and coach, and walked till I was dirty besides.

8. I walked in the Park to-day, in spite of the weather, as I always do, when it does not actually rain. Do you know what it has gone and done? We had a thaw for three days, then a monstrous dirt and snow, and now it freezes, like a potlid, upon our snow. . . . It was the coldest day I felt this year.

9. It has snowed all night and rains this morning. . . . At night. I dined to-day with my neighbour Vanhomrigh; it was such dismal weather I could not stir further.

11. It has rained all day, and there was no walking. . . . How do you pass your time this ugly weather?

15. I walked purely to-day about the Park, the rain being just over, of which we have had a great deal, mixed with little short frosts.

18. It being no day to walk, but scurvy rain and wind.

19. This proved a terrible rainy day. . . . This evening was fair, and I walked a little in the Park.

20. Morning. It snows terribly again. . . . At night. It grew good weather, and I got a good walk.

21. It rained like a dog [in the afternoon].

22. It snowed all this morning prodigiously, and was some inches thick in three or four hours.

23. The snow is gone every bit, except the remainder of some great snowballs made by the boys.

24. It is fine cold sunshiny weather. . . . I believe it is a hard frost.

28. I walked to-day into the city for my health, and there dined, which I always do when the weather is fair.

Mar. 1. A rainy day.

2. This rainy weather undoes me in coaches and chairs.

5. Our weather grows fine.

16. This delicious day.

17. O that we were at Laracor this fine day. The willows begin to peep, and the quicks to bud.

26. This was a most delicious day. . . . We have generally one fair day and then a great deal of rain for three or four days together.

27. A rainy wretched scurvy day, from morning till night.

April 2. We have such windy weather, 'tis troublesome walking.

5. This rain ruins me in coach hire.

6. We have not had five fine days these five weeks, but rain or wind. 'Tis a late spring they say here.

20. I dined in the city at a printer's, but it cost me two shillings in coach hire, and a great deal more this week and month, which has been almost all rain, with now and then sunshine, and is the truest April that I have known these many years. The lime trees in the Park are all out in leaves, though not large leaves yet.

26. We have had such a horrible deal of rain, that there is no walking to London.

27. Walked . . . to Chelsea, as I always design to do when it is fair.

29. I had a charming walk to and from town to-day.

30. Morn. . . . It rains hard. . . . At night. . . . 'Tis terrible rainy weather again.

May 1. The weather mending, I walked gravely home this evening.

2. A fine day, but begins to grow a little warm.

3. I did not go to town to-day, it was so terribly rainy.

6. It was a terrible rainy day; yet I made shift to steal fair weather overhead, enough to go and come in.

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8. It was bloody hot walking to-day. I dined in the city and came and went by water; and it rained so this evening again, that I thought I should hardly be able to get a dry hour to walk home in. . . . But the queen has not been able to touch, and it now grows so warm, I fear she will not at all. . . . I cannot sleep in the beginnings of the nights, the heat or something hinders me.

13. I rained all last night and this morning as heavy as lead; but I just got fair weather to walk to town before church. The roads are all over in deep puddle. The hay of our town is almost fit to be mowed.

14. I went to town to-day by water. The hail quite discouraged me from walking.

15. My walk to town to-day was after ten, and prodigiously hot.

19. Do you know that about our town we are mowing already and making hay. . . . Walked, in a fine moonshine night, to Chelsea, where I got by one.

24. At eight o'clock this evening it rained prodigiously as it did from five; however, I set out, and in half-way the rain lessened, and I got home, but tolerably wet; and this is the first wet walk I have had in a month's time that I am here.

25. It rained this morning.

26. It was a fine evening, and the footpath clean enough already after this hard rain.

28. It was bloody hot walking to-day.

30. I am so hot and lazy after my morning's walk, that I loitered at Mrs. Vanhomrigh's.

31. I was so hot this morning with my walk, that I resolve to do so no more during this violent burning weather. It is comical, that now we happen to have such heat to ripen the fruit, there has been the greatest blast that ever was known, and almost all the fruit is despaired of.

June 3. No boats on Sunday, never; so I was forced to walk, and so hot by the time I got to Ford's lodging, that I was quite spent; I think the weather is mad.

4. Heat and laziness and Sir Andrew Fountaine made me dine to-day again at Mrs. Van's; and, in short, this weather is insupportable. . . . How does Dingley do this hot weather? Stella, I think, never complains of it, she loves hot weather. There has not been a drop of rain since Friday se'enight. Yes, you do love hot weather, naughty Stella, you do so, and Presto can't abide it.

5. I am cruel thirsty this hot weather.

6. Morning. . . . I lie with nothing but a sheet over me, and my feet quite bare. . . . At night. I never felt so hot a day as this since I was born. . . . Then I walked home, and was here by ten, so miserably hot, that I was in as perfect a passion as ever I was in my life.

7. This abominable hot weather will force me to eat or drink something that will do me hurt. . . . If you have such summer there as here, sure the Wexford waters are good by this time. I forgot what weather we had May 6th; go look in my journal. We had terrible rain the 24th and 25th, and never a drop since. . . . 'Tis stewing hot, but I must rise and go to town between fire and water. . . . At night. . . . At dinner there fell the swingingest long shower, and the most grateful to me that ever I saw; it thundered fifty times at least, and the air is so cool, that a body is able to live; and I walked home to-night with comfort, and without dirt. . . . I am mighty happy with this rain: I was at the end of my patience, but now I live again. . . . O this dear rain, I cannot forbear praising it: I never felt myself to be revived so in my life. It lasted from three till five, hard as a horn, and mixed with hail.

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21. Came home by eleven and had a good cool walk; for we have had no extreme hot weather this fortnight, but a great deal of rain at times.

28. The days are grown sensibly shorter already, and all our fruit blasted.

30. Our hot weather ended in May, and all this month has been moderate; it was then so hot I was not able to endure it. . . . We have had a deal of scattering rain for some days past, yet it hardly keeps down the dust.

July 4. It has rained and hailed prodigiously to-day, with some thunder.

6. An ugly rainy day. I was to visit Mrs. Barton, then called at Mrs. Vanhomrigh's, where Sir Andrew Fountaine and the rain kept me to dinner; and there did I loiter all the afternoon, like a fool, out of perfect laziness, and the weather not permitting me to walk. . . . We had not a hot day all June, nor since.

7. It was the dismallest rainy day I ever saw. I went to the secretary in the morning, and he was gone to Windsor. Then it began raining, and I struck in to Mrs. Vanhomrigh's, and dined and staid till night very dull and insipid.

8. People here are troubled with agues, by this continuance of wet cold weather.

15. Here's hot weather come again yesterday and to-day.

17. Morning. I have put your letter before me, and am going to answer it. Hold your tongue: stand by. Your weather and ours were not alike; we had not a bit of hot weather in June, yet you complain of it on the 19th day.

23. Morning. It is a terrible rainy day, and rained prodigiously on Saturday night. . . . Night. . . . I just crept out to Mrs. Van's, and dined and staid there the afternoon: it has rained all this day.

24. We have had a great deal of wet these three days.

26. We had much rain to-day and yesterday.

27. The town is dull, and wet, and empty.

31. [Windsor.] The queen was abroad to-day in order to hunt, but finding it disposed to rain she kept in her coach.

Aug. 1. [Windsor.] The queen and I were going to take the air this afternoon, but not together; and were both hindered by a sudden rain.

17. The weather now begins to alter to rain.

18. [Windsor.] A fine moonshiny night.

20. It rained terribly every step of our journey to-day.

22. We have had terrible rains these two or three days.

23. I think our weather begins to mend. The roads are as deep as in winter. The grapes are sad things, but the peaches are pretty good, and there are some figs.

25. Days grow short, and the weather grows bad.

27. It is autumn this good while in St. James's Park; the limes have been losing their leaves, and those remaining on the trees are all parched.

28. We begin to have fine weather.

Sept. 1. The weather has been fine for some time.

4. Our journey was horrid dusty.

5. I found it had rained mightily in the night, and the streets were as dirty as winter; it is very refreshing after ten days dry.

8. Our fine weather is gone, and I doubt we shall have a rainy journey. The moon shone [on the journey to Windsor].

9. [Windsor.] Showers have hindered me from walking to-day.

12. It is terrible rainy weather, and has cost me three shillings in coaches and chairs to-day, yet I was dirty into the bargain.

13. It rained most furiously all this morning till about twelve, and sometimes thundered; I trembled for my shillings, but it cleared up, and I made a shift to walk in the Park.

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18. [Windsor.] This fine weather.
24. I had charming weather all last week at Windsor, but we have had a little rain to-day, and yesterday was windy.

Oct. 1. So you have had a long fit of the finest weather in the world.
2. [Windsor.] It has rained all this day, and I doubt our good weather is gone.
3. [Windsor.] The weather growing again very fine.
4. [Windsor.] It was the finest day in the world and we got out before eleven. . . . It rained a little this afternoon, and grew fair again.
5. [Windsor.] It grows bloody cold, and I have no waistcoat here.
6. [Windsor.] It is colder still.
8. It was frost last night, and cruel cold to-day. . . . The roads were as dry as midsummer to-day.
9. It rains hard this morning. I suppose our fair weather is now at an end. I think I'll put on my waistcoat to-day: shall I? . . . It rained terribly till one o'clock to-day.
14. I am glad I am not at Windsor, for it is very cold, and I won't have a fire till November.
18. 'Tis very cold; but I will not have a fire till November, that's pozz.
21. I never saw so fine a summer day as this was.
22. It cost me a shilling coming home; it rains terribly, and did so in the morning.
23. Terrible rain to-day, but it cleared up at night.
25. The queen is at Hampton Court; she went on Tuesday in that terrible rain. . . . It was a delicious day, and I got my walk.
26. I dined with Mrs. Van; for the weather is so bad, that I can't dine with great folks.
27. It has been a terrible rainy day, but so flattering in the morning, that I would needs go out in my new hat.
29. I was all this terrible rainy day with my friend Lewis.

Nov. 1. A fine day always makes me go into the city. . . . Our weather, for this fortnight past, is chequered, a fair and a rainy day; this was very fine, and I have walked four miles.
2. It has rained all day with a continuendo, and I went in a chair to dine with Mrs. Van; always there in a very rainy day.
3. A fine day this.
4. Bad slabby weather to-day.
5. 'Twas a terrible windy day.
7. It was a most delicious day.
9. I begin to have fires now, when the mornings are cold. . . . Fine weather.
10. I had good walking to-day in the city.
12. Morning. . . . I have not yet called to Patrick to know whether it be fair. It has been past dropping these two days. Rainy weather hurts my fate and my purse. He tells me 'tis very windy, and begins to look dark; woe be to my shillings! and old saying and true,

Few fillings,
Many shillings.

If the day be dark my purse will be light.

To my enemies be this curse,
A dark day and a light purse.

And so I'll rise and go to my fire, for Patrick tells me I have a fire; yet it is not shaving day, nor is the weather cold; this is too extravagant.
18. Why then, twelve-penny weather.
21. I walked home in the dusk, and the rain overtook me.
27. It was the dirtiest rainy day that ever I saw.
30. We have had much rain every day as well as you.

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Dec. 18. It has rained hard from morning till night, and cost me three shillings in coach hire. We have had abundance of wet weather.
19. Sad dismal weather.
22. It was a fine frosty day.
23. It is a terrible cold frost, and snow fell yesterday, which still remains; look there, you may see it from the penthouses.
24. It is now bitter hard frost, and has been so these three or four days. . . . 'Tis cruel cold.
25. I durst not go to church to-day, finding myself a little out of order, and it snowing prodigiously and freezing.
27. The frost still continues violently cold. . . . It is still prodigiously cold, but so I told you already.
31. Our frost is broken since yesterday, and it is very slabbery.

1712.

Jan. 11. I walked lustily in the Park by moonshine till eight, to shake off my dinner and wine.
12. 'Tis fine moderate weather these two or three days last.

Feb. 1. It was a most delicious day: Why don't you observe whether the same days be fine with you?
2. It threatened rain, but did not much.
4. We have no packet from Holland as I was told yesterday: and this wind will hinder many people from appearing at the birth-day, who expected clothes from Holland.
8. Well, Madam Dingley, the frost: why we had a great frost, but I forgot how long ago; it lasted about a week or ten days: I believe about six weeks ago; but it did not break so soon with us, I think, as December 29; yet I think it was about that time, on second thoughts.
9. It has been fine hard frosty weather yesterday and to-day.
29. I dined with a friend hard by, and the weather was so discouraging I could not walk.

Mar. 5. We have had mighty fine cold frosty weather for some days past.
9. The weather still continues very fine and frosty.
10. Our fine weather lasts yet, but grows a little windy.
13. Our good weather went away yesterday.
19. It was very windy walking.
21. The weather is warm these three or four days, and rainy. . . . It has rained all day, and is very warm.
22. The weather continues warm and gloomy. . . . Ugly nasty weather.
25. It has rained or mizzled all day.
26. I forgot to tell you that on Sunday last (March 23rd), about seven at night, it lightned about fifty times as I walked the Mall, which I think is extraordinary at this time of the year, and the weather was very hot.
28. The weather is bad again; rainy and very cold this evening.
29. The weather is abominably cold and wet.
30. It has rained terribly hard all day long, and is extremely cold.

April 24. The weather is mighty fine.

June 17. Last night . . . it rained hard. . . . We have had no thunder till last night, and till then we were dead for want of rain; but there fell a great deal: no field looked green. . . . It threatens rain.

July 1. We have had very little hot weather during the whole month of June; and for the past week we have had a great deal of rain, though not every day.

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17. I am dead here with the hot weather. . . . I am now sitting with nothing but my bedgown for heat. . . . We have had very little thunder here; none these two months. Why, pray, madam philosopher, how did the rain hinder the thunder from doing harm? I suppose it squenched it.

19. We had a good deal of rain last night, very refreshing.

Sept. 18. We have had most delightful weather this whole week.

Oct. 30. Our weather is abominable of late. We have not two tolerable days in twenty.

Dec. 12. We have lost our fine frost here; and Abel Roper tells me you have had floods in Dublin.

13. This is a fine day. I am ruined with coaches and chairs this twelve-penny weather.

18. We have terrible snowy, slobbery weather.

19. We are full of snow and dabbling.

20. Sad weather: two shillings in coaches to-day, and yet I am dirty.

1713.

Jan. 2. It continues cruel hard frosty weather.

3. Cruel cold weather.

5. Our frost is broke, but it is bloody cold.

6. It is scurvy rainy weather.

7. Very warm slabby weather.

13. Our weather is very bad and slobbery.

21. We had a prodigious thaw to-day, as bad as rain.

25. We had such a terrible storm to-day, that going to Lord Bolingbroke's I saw a hundred tiles fallen down; and one swinger fell about forty yards before me, that would have killed a horse: so after church and Court, I walked through the Park, and took a chair to Lord Treasurer's. Next door to his house a tin chimney-top had fallen down with a hundred bricks. It is grown calm this evening.

Feb. 1. It rained all this day.

8. Our weather is constant rain above these two months, which hinders walking, so that our spring is not like yours.

9. It was terribly rainy to-day from morning till night.

11. Yesterday and to-day have been fair, but yet it rained all last night.

15. Eleven at night, in terrible rain.

16. I never saw such a continuance of rainy weather. We have not had two fair days together these ten weeks.

19. Our weather continues as fresh, raining as if it had not rained at all.

23. It was ill weather to-day.

Mar. 3. The weather mends a little.

12. It was a fine day, which is a rarity with us, I assure you. Never fair two days together.

14. It was a lovely day this.

20. The weather being fine, I sauntered into the city.

23. 'Tis terrible rainy weather.

24. It rained all this day, and ruined me in coach-hire.

25. Weather worse than ever; terrible rain all day. . . . I can get no walks, the weather is so bad.

26. We had terrible rain and hail to-day.

28. Our rainy weather continues.

29. Terrible rain all day.

April 2. I have fires still, though April is begun, against my old maxim, but the weather is wet and cold. I never saw such a long run of ill weather in my life.

4. It rained all day.

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5. It was a very fine day, the first we have had a great while
6. I keep fires yet; I am very extravagant. . . . It is rainy weather again; never saw the like.
10. It rains every day, and yet we are all over dust.

June 6. [Chester.] All the ships and people went off yesterday with a rare wind.

The Depression of February 5th—7th, 1926.

In the early part of February of this year a depression, forming near to the Azores and travelling in a northerly direction, produced some unusual features in the weather over the British Isles and merited a closer study. By 7h. of February 5 the centre of the depression had arrived about 400 miles west of Valencia and the central part of it was occluded, the occlusion passing from just north of Valencia to Exmoor. Eastwards from this a warm front could be traced on the synoptic charts, while southwards passing close to Plymouth and Brest, a cold front was indicated. The two main rain areas, one in front of the warm front and occlusion, the other behind the cold front were quite definite at this time. During the succeeding 24 hours the warm front and occlusion together with the warm front rain area moved steadily northward; but little progress eastwards of the cold front occurred, while for a part of the morning on February 6 it was actually retreating towards the centre. Thus two currents existed side by side on almost parallel courses showing little temperature difference at the surface, but with considerable differences in the upper levels, as could be traced subsequently when these fronts passed high level mountain stations in France and Switzerland, *e.g.*, at Saentis there was a fall of approximately 11°F. with passing of the cold front.

At 7h. on February 6 this boundary could be located along a line southward from Renfrew across western Wales and thence south-south-east across Somerset and the western parts of France. The positions of the various "fronts" at 13h. are shown in Fig. 1, together with the two well-marked rain areas. A previous depression is shown occluded to the south-west of Scandinavia.[1]

Examination of the hyetograms for a number of places in different parts of England showed rainfall totals up to the passage of the warm front which did not vary very much from one another, the amounts ranging from 3.0 mms. at Lympne to 1.3 mms. at Croydon. At Plymouth the total was 2.2 mms.

During February 6, the position of the warm front changed very little. The cold front maintained its general N-S direction across southern Scotland and the Irish Sea, but further south an eastward movement had recommenced and the front appeared to pass Calshot about 18h. At Porton, with the assistance of records from electrically recording thermometers, some interesting temperature changes were shown. Throughout the night February 5-6

[1] In the Norwegian polar front theory, a depression consists of a wedge of warm air intruding to the centre of the area of low pressure. The surface separating the warm air from the preceding colder current is termed the warm front; that separating the warm air from the overtaking cold air is termed the cold front. When the warm air is entirely lifted off the surface the depression is said to be occluded. Then, only one line of discontinuity (or abrupt change) can be detected on the chart. This line is called the line of the occlusion.

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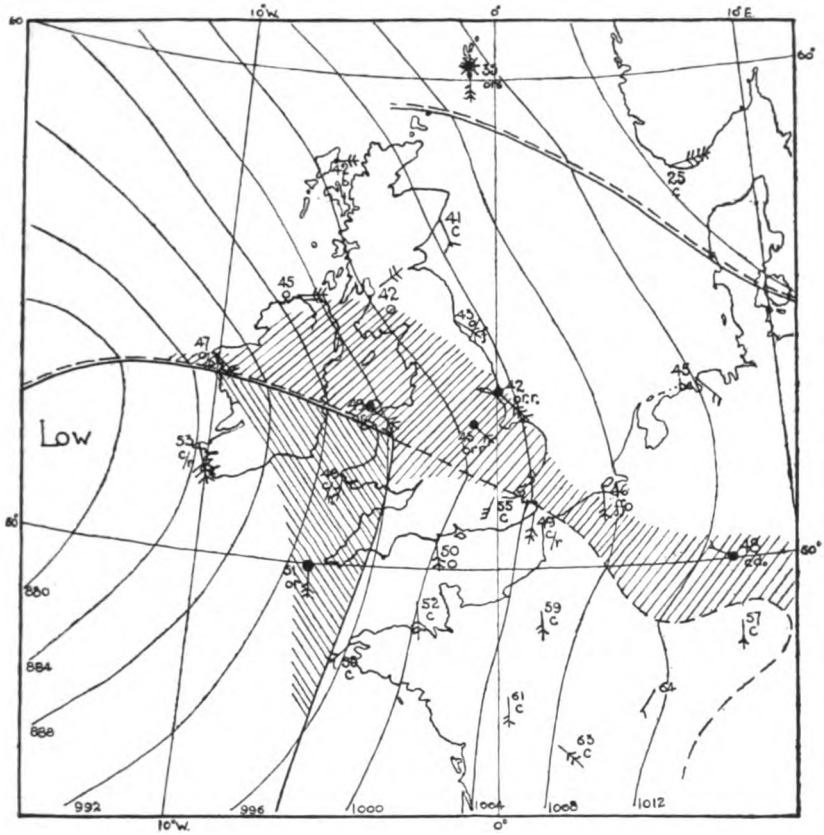

FIG. 1.—Weather Chart, Feb. 5, 1926, 13 h. —— Cold front; — — — Warm front; ═══ Occlusion; Rain areas; Warm front; Cold front.

inversions were formed, but during the day the magnitude of the inversion increased, reaching its maximum value as below:—

$$T_{17.1m.} - T_{1.2m.} = +1.2°F. \text{ at } 13.36h.$$
$$\text{and } T_{7.1m.} - T_{1.2m.} = +1.0°F. \text{ at } 13.40h.$$

($T_{17.1m.}$, $T_{7.1m.}$ and $T_{1.2m.}$ are the respective temperatures at 17.1, 7.1 and 1.2 metres from the ground.)

Later the amount of the inversion decreased, becoming zero at 15.44h. and the lapse rate became normal. At 17.20h. a maximum value was found equal to 1.5°F. for $T_{1.2m.} - T_{17.1m.}$. Thus the cold front was advancing as a wedge with a very small angle of slope and at a relatively low speed.

Up to this time such precipitation as fell on the eastern and western sides of this cold front could be stated as precipitation belonging to the warm sector or as cold front precipitation, respectively, and the contrast between these amounts is very apparent. The warm sector precipitation was rather heavier nearer to the cold front and less further away, *cf.* 5.4 mm. at Calshot, 0.5 mms. at Lympne and 0.4 mms. at Cranwell, while in the cold air there were such amounts at 13.3 mms. at Plymouth and about

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16 mms. at Holyhead and Pembroke; all these amounts falling in approximately 24 hours.

Other changes were now beginning to show themselves, for along the plane of separation of the two air currents new shallow depressions began to form and travel along the boundary. One such, forming in the south-west of France, spread north-eastward across France and then over S.E. England, producing 14 mms. of rain at Farnborough between 18h. of the 6th and 7h. of the 7th, while 13 mms. of rain fell at Birmingham, 19 mms. at Sealand and 27 mms. at Liverpool between 7h. and 18h. of February 7.

The varied changes of weather during this period of 48 hours together with the probable formation of new depressions and their prospective paths were possible to forecast provided one could trace with reasonable accuracy the warm front, cold front and occlusion respectively throughout the period, but by any other method the changes would have been much less easy to follow or forecast.

R. S. READ.

OBITUARY.

Mr. C. E. DE BERTODANO, M.Inst.C.E.

We regret to learn of the death of Mr. C. E. de Bertodano.

From 1902 until recently he maintained observations at Cowbridge House, Malmesbury, Wilts.

He spent several years in Spain as assistant engineer to the Valencia Land Company, formed for the development of roads and irrigation schemes for the cultivation of rice on the Mediterranean coast of Spain. On account of the Carlist War he had to leave, and in 1872 he returned to London and accepted an appointment under the Manchester Corporation.

He then held various posts in the Argentine, in Spain, and in the Philippine Islands, and in 1907 he joined the technical staff of Sir John Aird & Co.

He was a Fellow of the Botanical, Zoological and Royal Horticultural Societies, and was elected a Fellow of this Society in 1887.

Information has also been received of the deaths of Mr. J. H. CASARTELLI, Mr. A. S. MARRIOTT, and Mr. W. J. HOWARD SMITH, but no particulars are available.

Mr. Casartelli was elected in 1910 and died April 18, 1925. Mr. A. S. Marriott was a Life Fellow, elected in 1887, and is reported to have died several years ago. Mr. W. J. Howard Smith was also a Life Fellow, and was elected in 1894.

REVIEWS.

Atlas Elemental de Nuvols. By EDUARD FONTSERE. Barcelona (Gustau Gili, Editorial), 1925. 4to. Pp. 54, pls. 32.

This cloud atlas published by the Meteorological Service of Catalana is a worthy successor to the well-known official atlases published in England, France, Italy, and the United States of America. Within recent years we have had numerous proofs of the energy and efficiency of Prof. Fontseré's establishment at Barcelona, and this new publication, as well as being a most valuable addition to existing cloud literature,

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is a remarkable example of what can be done by a small institution in favourable circumstances.

The atlas is a substantial quarto volume containing thirty-two plates from photographs by J. P. Girbau, G. Campo and A. Pulvé. In addition to the large plates, the text, which is printed both in Catalan and French, contains a number of small pictures in colour. The colour effect is obtained by over-printing the sky in blue and is very successful. Though presumably more expensive, the result is so much better than the common device of printing high clouds in solid blue and low cloud in solid black that we hope it will be widely imitated. The plates are, for the most part, excellent, but the use of deep colour filters has been pushed to excess in some instances, producing a singularly unreal appearance. Plate XXIV. (cumulo-nimbus) is a particularly bad example of this, although the form of the cloud is illustrated clearly enough. Plate VII. is a remarkably beautiful illustration of cirro-stratus, and many of the other pictures are a delight to the eye.

The text is very well written and forms as good an introduction to the study of clouds as could be desired. The International Classification is adhered to, but certain varieties are distinguished by specific names, *e.g.*, cirrus virgula, cumulus congestus. Gen. Delcambre contributes a foreword in which the value of cloud study is emphasised, and we note that Capt. Ph. Wehrlé was responsible for the French translation of the original text. The paper and printing contribute materially to the general distinction of the whole work.

E. G. B.

Elettricita Atmosferica. By Prof. CARLO NEGRO. Milan (Ulrico Hoepli). 1926. 8vo. Pp. xvi + 299, with 40 figures in the text. 36 lira. (Published under the auspices of the Italian Meteorological Society.)

Of the eight chapters in this book, Chapter I., pp. 1-70, deals with potential gradient; Chapter II., pp. 71-139, with the ions of the atmosphere; Chapter III., pp. 140-164, with the electricity of rain; Chapter IV., pp. 165-197, with radioactivity, including the penetrating radiation; Chapter V., pp. 198-237, with thunderstorms and allied phenomena; Chapter VI., pp. 238-249 (rather slight), with earth currents and aurora; Chapter VII., pp. 250-260, with various hypotheses; and Chapter VIII., pp. 261-279, with radio-telegraphy and atmospherics. Two appendices, pp. 280-299, are mainly devoted to a historical resumé of Italian work.

Until recent years the only text-books on the subject were German, but recently there have appeared two notable French works—by Chauveau and by Mathias and collaborators. In English there are only encyclopædia articles, necessarily short, and a discussion of certain aspects in a publication of the Carnegie Institution of Washington. We have now a choice of an Italian volume, and the question arises whether it is superior to the other foreign works, or specially complete in any one department. The principal text-books in German—those by Göckel and by Mache and von Schweidler—are pre-war, and so hardly up to date. Thus it is natural to compare the present book with the French works mentioned above. In character it has more resemblance to the work of Mathias than to that of Chauveau. Except in the case of potential gradient the latter work contains very few numerical data, largely on the ground that their accuracy is doubtful. The present work has numerous tables of data, but comparatively few of the data are from Italian sources. Information on this point is easily derived from the references, between 300 and 400 in number, given at the foot of the pages. A somewhat remarkable fact is that more than half these references date from 1900 to 1910, and only about a quarter from more recent years. For a text-book of to-day the space allowed to dissipation and radioactive results obtained by Elster and Geitel's methods appears some-

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what excessive, though possibly Mathias's work may go to the opposite extreme.

Recent foreign work, unless included in some text-book, largely escapes notice. The potential gradient data on p. 39 seem taken with two exceptions from a table given by Hann in 1914, and the two-hourly diurnal variation data on pp. 47-49 seem mainly due to Mache and von Schweidler. It is now supposed that potential gradient is lower at Potsdam than at Kew, and not 60 per cent. higher, as it is according to the old data quoted. Other data want revision. Thus on p. 47 we have 215 v/m. for the Eiffel Tower, while the correct value 2150 v/m. appears on p. 49.

Various of the author's data seem somewhat easily come by. Thus of the discussion in pp. 160-164 of the rainfall results of Simpson and Baldit, pp. 160-163 are essentially an Italian translation and p. 164 a direct extract from Mathias's work. This is openly done. But when wholesale adoption is indulged in, greater care should be taken to ensure accuracy. On p. 163 a mistake in Mathias's work, 10^{-5} amp./cm^2 for 10^{-15} amp./cm^2, is reproduced, and 286 is written for Mathias's 2,86 (*i.e.*, 2.86) in the value of a ratio. A good many other slips have caught our eye.

Another long quotation is the questionnaire on lightning to Italian observers, which extends from p. 229 to p. 237. The curiosity displayed seems boundless, and is far from being confined to physical topics. Thus question 41, slightly abbreviated, runs: "If you ate the flesh of any animal killed by lightning, was the taste good or bad, and did you have any stomachic trouble?" It would have added to the interest if the half-pages left blank, as in the original questionnaire, had been filled in with suitably selected replies.

In the original French, the 42 resolutions passed by the Section of Terrestrial Magnetism and Electricity at the Rome and Madrid meetings of the International Union of Geodesy and Geophysics are reproduced on pp. 288-293. This should be gratifying to the officers of the Section, but may seem to others rather a luxury, seeing the small number of the resolutions which really apply to atmospheric electricity.

The book, though unequal, has considerable merits, and should arouse increased interest in the subject in Italy, but we should not recommend it as an *alternative* to the work of Mathias.

C. CHREE.

Clouds and Weather Phenomena for Artists and other Lovers of Nature. By C. J. P. CAVE. Cambridge (University Press), 1926. 8vo. Pp. x+31, pls. 23. 5/- net.

This little book is addressed, as its name implies, to those for whom the clouds, the sunset, the rainbow and the mist are things to be studied for their beauty rather than for their scientific interest. A lack of disciplined knowledge to temper the artist's enthusiasm may, and often does, lead the painter into errors of fact which may seriously affect the value of his works in the eyes of those who are sufficiently well informed to notice such mistakes. While admitting that the exact delineation of natural objects is not the sole function of art, there can be no question that accuracy in rendering what are supposed to be definite cloud forms in a picture cannot fail to increase the beauty of the whole composition. Moreover, landscape painters as a class seem strangely averse from including any forms other than cumulo-nimbus in their skies. Captain Cave's book will have served its purpose if it does nothing more than stimulate some of our painters to vary the formula a little.

The book consists of a collection of cloud photographs preceded by thirty pages of letterpress dealing in simple and popular style with the colour of the sky, sunset colours, optical phenomena, clouds and the

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moon. Though not of meteorological interest, the section dealing with the moon is particularly valuable and seems likely to save artists from serious blunders, such as the representation of a crescent moon on the northern side of the sunset. The statement on page 22 that stratus cloud "is generally seen in isolated patches, which are often lenticular in shape," is contrary to fact, and the present reviewer would have preferred to see the photographs reproduced on a larger scale. These are, however, only minor blemishes in a most useful and informative little volume.

E. G. B.

The Climates of the United States. By ROBERT DE COURCY WARD. New York; London (Ginn & Co.), 1925. 8vo. Pp. xvi + 518. Maps and diagrams.

Professor Ward has for a generation been known as an earnest student of climatology and a writer of distinction, and now from the security of Harvard there comes another book from his pen and one for which there was abundant room. The book in a way serves as a landmark; for the story of American meteorology falls into two main chapters—that which precedes and that which follows the creation of the Weather Bureau in 1890. The later story is one of highly efficient organization, the labours of a group of able investigators, and the accumulation of a rich store of observations which has only now rendered possible such a considered study as that which Prof. Ward has provided. But the former chapter is almost more inspiring, and one looks back with admiration on early activities more vigorous than anything attempted in England at that time—the work of the first observers, the labours of the Smithsonian Institution under Henry, and the recognition more than a century ago by the central government of the fact that meteorological observations were a matter of national concern. One recalls also the researches of such men as Redfield and Espy; whilst Lorin Blodget's *Climatology of the United States* (1857) ranks amongst the classics, with its vividly drawn contrasts of North America and Eurasia, and an almost prophetic insight into the economic possibilities of the author's only half-developed country.

Professor Ward's book follows logical lines. The major controls are first considered; of great importance are the offshore winds which give to the Eastern States a continental rather than a littoral climate, and the absence of transverse mountain ranges which makes the climatic transition in going from south to north everywhere slow and gradual. In Chapter 4 the "Weather Element" is abundantly illustrated by maps, and by diagrams prepared in the Climatological Laboratory of Harvard.

Chapters 5 to 13 deal with climatic elements that for the most part can be instrumentally measured—temperature, rainfall, sunshine and so forth. Everywhere exhaustive studies by the Weather Bureau staff are appealed to, and the variety of interest is great. Thus temperature has risen as high as 134°F. on the edge of Death Valley, California; whilst in the Eastern States the sudden, short penetrations of low minima far to the south are a disconcerting feature of the climate. On all counts the minimum thermometer appears to have a greater human and economic significance than the maximum. The study of rainfall "types" is convincing, and we find the heaviest 24 hours' rainfall along the coast of Texas and Louisiana in connection with West Indian hurricanes and not along the north Pacific coast with its higher annual rainfall. And a hostelry with the delightful name of Paradise Inn must surely have been christened in summer, for the snowfall there, on the south slope of Mt. Rainier, Washington, at an elevation of 5,500ft., during the winter of 1916-1917, was no less than 790in. Those who can only dip into the book might well turn to a fine summary of McAdie's splendid studies of the

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San Francisco fogs, which, from May to October, "with clockwork regularity . . . march in every afternoon and cover the brown hills."

Climatic phenomena in the United States develop on the grand scale, and Chapters 14-18, which deal with such manifestations as Thunderstorms, Tornadoes, Blizzards, Hot Waves, and Chinook Winds, are full of interest. See, for example, a diagram on p. 339 indicating where in a mountainous region the greatest risk from lightning is encountered; or the graphic description (p. 410) of a "chinook" in Montana with a rise in temperature of 34°F. in seven minutes.

Prof. Ward had started out by dividing the United States into five climatic provinces—Eastern, Gulf, Plains, Plateau, and Pacific—and Chapter 20 is an admirable summing up of four-fifths of the whole book and describes the essential characteristics of these provinces. The two following chapters discuss "Climate and Health" and "Climate and Crops."

The book with its numerous references is almost an encyclopædia of its subject. We are inclined to think that it would have been even more useful had some few pages of statistical tables been included; but after all, the Weather Bureau is so generous in distributing its publications that such standard works as Bulletins Q. and W. are readily accessible. And we bear Prof. Ward a slight grudge that he is so loyal a citizen of his great country. A climatologist should know no territorial boundaries, and an excellent book might have been made richer by more numerous comparisons with other countries. A study of the climate of Alaska is properly included (Chapter 23); but otherwise a cold silence is maintained as to anything north of the 49th parallel. Yet this criticism also may be unfair; and the learned author has given us a book for which we are very grateful. Meteorology owes much to Harvard.

A. W.

Notions de Météorologie Générale et Nautique et Eléments d'océanographie. By MARCEL COYECQUE. Paris (Berger-Levrault, Editeurs), 1925. 8vo. Pp. x + 383. 15 fr. net.

The purpose of this book is to give to seamen an account of the modern methods of meteorology. It contains a résumé of the instruments used, a description of the general circulation of the atmosphere based on the conceptions of the Norwegian School, some chapters on the ideas that form the basis of dynamical meteorology, and an account of the methods of forecasting obtaining in France. It is planned, it appears, to be used as a text-book by the officers and cadets of the French Navy and Mercantile Marine, but it is not intended that it should enable these officers to construct their own weather maps and forecasts at sea. Those functions, the author states most emphatically, should be entirely confined to an organization controlled by meteorologists in communication with a widespread network of ships. It is probably on this account that the practical difficulties of weather forecasting at sea are not discussed in the detail which the reader would naturally expect from a work on marine meteorology, but nevertheless it is a little disappointing that almost all the illustrations of forecasting methods are taken from charts made from land stations and not those actually made at sea in the *Jacques Cartier*, in which ship the author is in charge of Meteorological Services. As a result of this the reader is rather prone to question how far the methods of forecasting advocated are feasible at sea. In particular, while great emphasis is laid on the method of isallobars, it is not at all clear how this method can be used with observations from moving ships.

It would seem that the author presupposes in his reader a certain knowledge of the physical laws which underlie the modern conception of dynamical meteorology, but it would probably have enhanced the value

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of the book if those laws had been enunciated; as it is, the lay reader may find difficulty in following the logic of some of the reasoning.

It is to be regretted that references are omitted to the majority of works from which the author has taken the theories he puts forward.

C. S. D.

Das Eiszeitliche Klima und seine geologischen Wirkungen im nicht vereisten Gebiet. Von Prof. Dr. PAUL KESSLER. Stuttgart, E. Schweizbart 'sche Verlagsbuchhandlung (Erwin Nägele) G.M.B.H., 1925, 8vo. Pp. 210, illus. 13 mark.

The greater part of this book deals in considerable detail with the geological phenomena of the Quaternary ice age in the unglaciated region between the Scandinavian ice-sheet to the north and the Alpine glaciers to the south. The phenomena include "earth-flows," mounds, ridges and terraces of angular or sub-angular blocks, "stone rivers" and "head" (Gehängeschutt) formed in the neighbourhood of steep slopes. These formations often present a deceptive similarity to glacial moraines, and are classified by the author as "pseudo-moraines." The author then proceeds to investigate the climate of this "periglacial" region. He has three lines of attack—the present climatic conditions in the continental foreground of ice-sheets, the fauna and flora of the periglacial regions, and the geological phenomena already described. The periglacial regions available for study at the present day include the borders of Spitsbergen, Greenland, and the Antarctic continent; the data which are employed are not the most recent and complete (for instance, the discussion of the climate of Spitsbergen is on the basis of the observations at Mossel Bay in 1872 to 1873), but in any event none of the regions present sufficient similarity to the conditions of central Europe during the ice age for the conclusions to have much value.

The study of the fauna and flora gives results of great interest. The similarity of the plants at high levels in the Alps to Arctic forms suggests that during the maximum extension of the ice, these cold-loving species inhabited the low unglaciated ground north of the Alps and afterwards followed the retreating glaciers upwards to high levels. The general picture is one of a tundra region, inhabited by the reindeer, the woolly rhinoceros and the mammoth. The geological phenomena point to frost action on a huge scale, the earth-flows and block trains moving down the valleys under the action of repeated freezing and thawing. The general climate of the region appears to have been highly abnormal. The prevailing winds at the surface were probably dry glacial winds from the north-east, but these were shallow and were overlain at a small height by moist winds from the Atlantic, which sometimes descended to ground level. The snow-line lay at 3,000 feet in the west and 5,000 feet in the east, and in the hills the accumulations of snow carved out cirques or corries. These are mainly on the north-eastern side of the crests, and since Enquist has shown that the greatest accumulation of snowfall takes place on the lee-side, they indicate that the snow-bearing winds at that level came from the south-west. Even over low ground the mean annual temperature was below 28°F.; the winter temperatures were very low, but the summers may have been hot at times; the variability of the temperature was great. The annual precipitation was small, but occasionally rain fell in torrential downpours. The evaporation was very great, and one of the greatest peculiarities of this cold periglacial climate is that it aped the formations of the hottest deserts. An important deposit was the loess formed in a semi-arid climate from the finest wind-blown dust; and there were even small salt lakes in which layers of salt were formed. It is noteworthy that similar saline deposits are forming at present in restricted areas in Spitsbergen and Greenland.

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The book is a definite contribution to the study of Quaternary climates, and the region with which it deals is one of vital importance for the distribution of plants and animals at the present day. Meteorologists will find the opening geological sections rather wearisome, and should turn at once to page 144, where the author begins the systematic discussion of the periglacial climate. It may be remarked that reference would have been facilitated had the author divided his material into chapters in the orthodox way.

C. E. P. B.

Hydrology and Ground Water. By J. M. LACEY. London (Crosby Lockwood & Son), 1926. 8vo. Pp. viii + 159. Price 12s. 6d.

The book is described as "a practical text book for the use of civil engineers, surveyors, students and all those who deal with the control of water." It is written by a Civil Engineer with very considerable practical experience, especially in India.

The first three chapters are devoted to rainfall, and so far as the meteorologist is concerned, the book must be largely judged by these chapters. The difficulty of summarizing our knowledge of rainfall in 16 pages could have been overcome by a greater use of references. No mention is made of the only recent text book on rainfall, *The Rainfall of the British Isles,* by the late Mr. Carle Salter. It would have been interesting if the author had set out the evidence for the statement that "the height of maximum rainfall in Cumberland is about 2,000ft. above sea level." In the chapter on "The Relation of Rainfall to Configuration" in Salter's book, a diagram is given comparing the rainfall and the configuration of a section of country across the Lake District. The greatest rainfall, of 170 inches, is shown to the leeward of Great Gable, which approaches 3,000ft. in height.

In the chapter on evaporation, there is some obvious disparity between the figures for evaporation at Staines Reservoir and at Camden Square (London). The values for Staines are quoted for 1903 and 1904 as 26.3 inches and 22.8 inches respectively, while the average annual value for Camden Square is also given, viz., 15.5 inches (the recorded evaporation for 1903 and 1904 being 16.9 inches and 16.4 inches). No indication is given as to which of these series of observations is more representative of the loss by evaporation in the case of reservoirs or gathering-grounds. The observations of evaporation at Camden Square are incorrectly described on p. 27 as "soil evaporation" and correctly on p. 21 as from a 6ft. square tank filled with water.

Chapter V. deals with the flow of water through a porous soil. It is shown that if the water contained in the soil or sand exceeds that required for complete saturation, the soil looses its stability, and has a tendency to flow, the phenomenon being observed in the sandy beds of Indian rivers after the flood season is over. The geological conditions controlling the occurrence of percolation wells and springs are next described and illustrated by diagrams. The important question of the relation of the run-off to the actual rainfall is described in some detail, and references are made to the results from a number of catchment areas. Some of the most remarkable heavy falls of rain in short periods recorded both in these islands and in India are given, and various formulæ for estimating flood discharges are discussed. The problem of how much money should be spent in preventing or lessening the chances of damage due to these floods is still an important problem for the civil engineer. The subject of ground water, the supply that can be derived from wells and the selection of sites for wells, is considered in detail. An exhaustive summary is also given of the subject of wells as a source of water supply, both from the theoretical and practical standpoints. J. G.

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METEOROLOGICAL CONDITIONS AND SOUND TRANSMISSION.

By E. S. PLAYER.

(Technical Assistant in the Acoustical Section of the Air Defence Experimental Establishment.)

Communicated by D. BRUNT, M.A.

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During the summer of 1925 a series of flights by R.A.F. machines was organised for experimental purposes. These flights afforded opportunities for making observations on the various effects of meteorological changes on the sound transmitted from aeroplanes in flight—often at long range. These effects, as recorded both by ear and instrument, were so marked and so exactly in accordance with previous experience as to justify special consideration.

Before entering into details as regards recent experience, a conception of the complexities involved will be more easily arrived at by first reverting to experiments[1] carried out by the author at Joss Gap, near the North Foreland, during the years 1921-22. The experiments were organised for the purpose of systematically studying, over a long period, the subject now under discussion. The source of sound was the siren of the North Goodwin light-vessel (bearing 122°) at a fixed distance of seven miles, the pitch (corresponding to a frequency of 180 vibrations per second) being always approximately the same. In order that the work could be of a more exhaustive nature, the Elder Brethren of Trinity House granted the privilege of special blasts of the siren over limited periods of certain days each week. Thus, instead of being confined to weather of the type which necessitated blasts for the purposes of navigation, observations could be made under various conditions. The light-vessel in question was in telephonic communication with the shore, and advantage was taken of this, not only to establish the necessary co-operation of the light-vessel's crew and those at the observing station, but also to compare the respective local weather conditions, but, unfortunately, sea and air temperatures were not obtainable from the light-vessel. During the experiments the author was enabled to spend five weeks on the light-vessel, so that observations could be made of sound travelling in opposite directions during the same conditions. The source at

[1] Conducted under the supervision of Dr. W. S. Tucker, Director of the Acoustical Section.

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the station was a standard manual fog-horn, lent for the purpose by the Elder Brethren. Observations were made aurally as well as by electrical and photographical recording instruments. Built into the cliff at the station there was also a concrete acoustical mirror, spherical in form, with a focal length of 4ft. 9in. The experimental work was not confined to the North Goodwin alone, but was extended, at times when their sireens were blowing, to the following light-vessels:—

Name of Light-Vessel.	Distance.	Bearing.
Tongue	9 miles	346°
Kentish Knock	19 miles	26°
East Goodwin	12 miles	147°
South Goodwin	15 miles	175°

Many of the results obtained have already been published,[2] but the following examples, being of special interest, may be quoted here.

Soon after the inauguration of the work it was recognised that acoustical conditions would change on frequent occasions continually and with great rapidity. This is evidenced by the results here shown in tabular form, which give the variations, from minute to minute, of the intensity of the sound received from the North Goodwin siren.

TABLE I.—VARIATIONS IN INTENSITY OF SOUND RECEIVED FROM THE SIREN OF THE NORTH GOODWIN LIGHT-VESSEL, MARCH 12, 1921, 3.50 P.M. TO 4.34 P.M. (B.S.T.).

Bearing, 122°. Wind, 215°, 12 m.p.h. Interval between blasts, 1 minute.

Blast.	Galvanometer Deflection.	Blast.	Galvanometer Deflection.	Blast.	Galvanometer Deflection.
1	1	13	4	33	3
2	4	14	3	34	3
3	1	15	3	35	5
4	0	16	1	36	3
5	0	17	3	37	7
6	5	18	1	38	2
7	1	19	2	39	1
8	1	20–28	0	40	0
9	6	29	5	41	8
10	1	30	9	42	1
11	1	31	3	43	1
12	1	32	9	44	2

No further deflections were recorded and the siren became inaudible, although blowing till 5.5 p.m.

The measurements were given by the deflections of a galvanometer connected to a Wheatstone bridge, one arm of the latter being formed by a doubly-resonated hot-wire microphone,[3] which acted as a receiver. While the readings were being taken, the velocity of the wind on the surface was 12 m.p.h., direction 215°. It was

[2] Tucker, W. S., *Proc. R. Soc. of Arts*, **71**, 1923, pp. 121-142.

[3] Tucker, W. S., and Paris, E. T., *Phil. Trans. R. Soc.*, **221A**, (1921), pp. 389-430, and Paris E. T., *Proc. R. Soc.*, **101A** (1922), pp. 391-410.

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thought at the time that the results were due to wind effect, but when the experiment was repeated a few days later, at a time when the wind velocity was only 2 m.p.h., and therefore negligible, the variations in sound intensity were much greater than on the previous occasion. Hence we may consider influences other than the wind when searching for an explanation.

That humidity has a definite effect on the length of range over which a sound can be heard, may be gathered from the results shown in the diagram Fig. 1, where it will be seen that a reduction

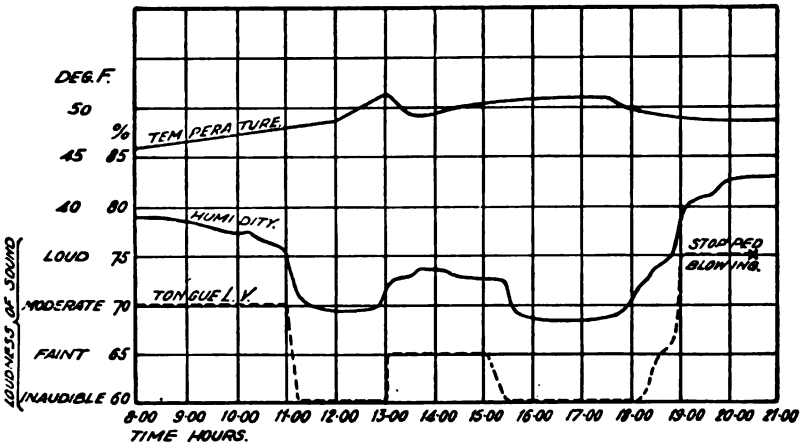

FIG. 1 - COMPARISON OF HUMIDITY CURVE WITH THE CURVE OF AUDIBILITY OF THE SIREN OF THE "TONGUE" LIGHT VESSEL. APRIL 21ST 1921

in the audibility of the sound corresponded with a reduction in the amount of moisture in the air. Observations of the sound, which were continued closely throughout the day, were made aurally. When the siren note became fainter at 11 a.m., an inspection of the hygrograph showed a sudden drop in humidity and the writer watched the pen falling while listening at the same time to the sound dying down to inaudibility. At the times when the siren had become audible again, the same procedure was followed.

An exceptional example of temperature effect was obtained on July 19th, 1921, during a prolonged period of drought. The siren was blown during the forenoon, the wind being off shore and directly adverse (N.W.) with a bad gradient, the surface velocity of 12 m.p.h. rising to 20 m.p.h. at 1,000 feet and remaining nearly at that speed up to 2,000 feet, after which there was a drop in the velocity. In such conditions, especially as there was a fair amount of sea noise, there seemed little likelihood of the siren being audible at the station. So confident was the writer of this, that when telephoning instructions to the master of the light-vessel to commence blowing, he remarked that he neither expected to hear the siren nor to obtain any records. This judgment was wrong, for the galvanometer gave some of the greatest deflections obtained

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during the experiments, and the siren was abnormally loud to the ear.

The explanation of this apparent anomaly may be found in the fact that the wind had passed over many miles of land exposing a surface at an unusually high temperature. (Three inches below the surface of exposed ground the temperature was 9° Fahr. above that of the screened thermometer.) After passing from land to sea the lower stratum of the air current would probably suffer a reduction in temperature through being in contact with the cool surface of the sea, whereas the higher strata would not be appreciably affected. In this way a favourable temperature gradient would be produced, the tendency of which would be to neutralise the adverse effects of the wind, and also to set up good conditions for sound transmission.

A type of weather with which all are familiar deserves notice, as it is of peculiar acoustical interest. The type referred to occurs during the warmer months, and is commonly described as "oppressive." There is little or no movement of the air, the sky is cloudless, but there is a definite haze which appears to be at an altitude and slightly dims the sun; shade temperatures are higher and temperatures in the sun lower than the average for the time of the year.

The worst acoustical conditions, as regards sounds originating on the surface, were almost invariably found on such days as these, although sounds from above, such as are emitted from an aeroplane, were transmitted well. This difference in transmission may be largely due to the existence of convection currents and, with conditions as just described, the effects of insolation on still air and the earth's surface would be favourable to the formation of these. However, in cases as the above, before looking for the causes, it seems essential that one should be in possession of data relating to upper air conditions (local), and these, unfortunately, were not obtainable on the station where the observations were made. The subject is one which invites further and more elaborate investigation.

For miles round Joss Gap the country is flat, and therefore no winds anabatic in nature were experienced, but these would be looked for in a more broken country and be the cause, perhaps, of considerable modification in acoustical conditions, a fact that indicates the necessity of judgment when selecting a site for acoustical observations.

Much could be written on the observed effects of rain, but these apparently are so inconsistent and contradictory that each case would have to be considered individually, and space does not permit this. The subject, therefore, can only be lightly touched upon here.

On twenty-one occasions when rain was general, the siren was audible on nine and inaudible on twelve. The manner in which these group themselves suggests seasonal influence. From May to September, inclusive, the siren was audible on six occasions, inaudible on two; from October to March, audible on two occasions, inaudible on nine. Again, sometimes when the siren was blowing, but inaudible, it would become audible during a period of rain and

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die out again when the rain stopped; on other occasions the exact opposite was the case.

When considering the effects of rain, or those of any other constituent condition, these must be balanced against the weight of the other influences prevailing. The whole crux lies in forming a correct estimate of the relative values of the constituents, and hence their powers to reduce, neutralise, or assist each other's influence. It was found, however, that there are occasions when it is possible to single out a component—wind, temperature, rain, cloud, etc.—and isolate it as the ruling factor of acoustical conditions at a particular time.

Reference has been made to the station being equipped with an acoustical mirror. This was used for the assistance given by its magnifying power to the listener. At times when the siren was inaudible to the unaided ear, it could often be heard by an observer standing with his head in close proximity to the mirror focus, thereby gaining a definite increase in listening range.

At the termination of the investigations at Joss Gap, the data and knowledge gained made it possible to reduce certain combinations of conditions to classification and, the listening range for each type of combination being always approximately the same, to foretell with some degree of certainty whether the siren note would be loud, moderate, or inaudible.

The above experiments dealt with the transmission of sound through conditions contained within strata lying close to the earth's surface; therefore these conditions would be influenced by local variations of temperature and humidity due to changes in the thermal character and other properties of the different substances forming the path over which the sound travelled—for instance, the change from sea to land.

It is obvious that many complexities will be met with in investigating the transmission of sound along the surface (the source being stationary), and also that these are likely to be increased when the sound under observation is from a moving source and arriving from an altitude, as is the case with the note of an aeroplane. The path in this case traverses conditions varying, often abruptly, to such an extent that they can generally be divided into well-defined strata.

During the experimental flights last summer (1925), data of the local meteorological conditions of the upper air were frequently obtained by an observer[1] who made flights for this purpose in a Bristol Fighter, readings of temperature and humidity being taken as different altitudes were reached. The results show that the path of sound travelling from an altitude would often have to pass through conditions so widely different that it is hardly likely that anything of a like nature could occur near the surface—at any rate within limits which would extend far beyond those of ordinary listening range. When comparing the two cases, one might therefore expect to find that range from an altitude is subject to just as great and frequent changes as range along the surface.

[1] These readings were taken for the Acoustical Section by Mr. J. G. Goodyear, of the Meteorological Office, Air Ministry.

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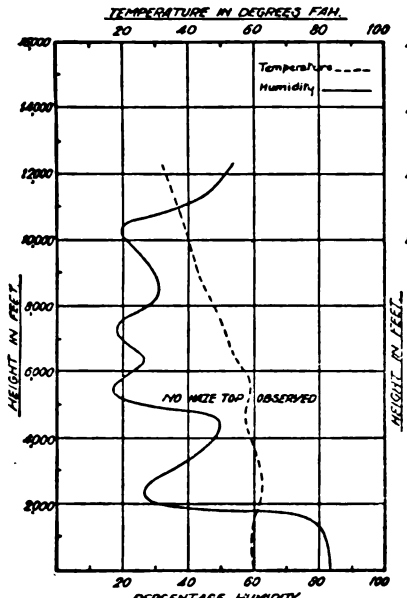

FIG 2 - TEMPERATURE AND HUMIDITY OF THE UPPER AIR ON JULY 13TH 1925. TIME 8-35 PM (S.T.)

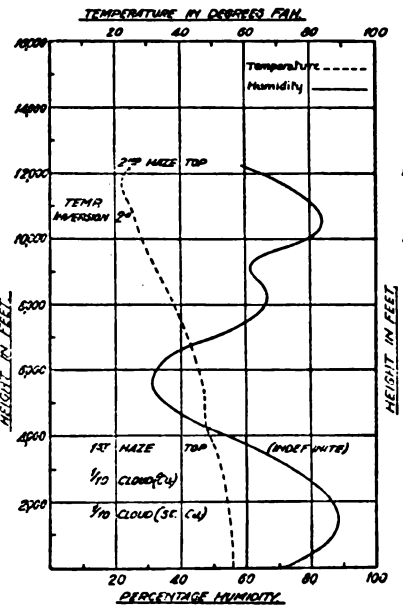

FIG 3 - TEMPERATURE AND HUMIDITY OF THE UPPER AIR ON JULY 28TH 1925. TIME 7 P.M. (S.T.)

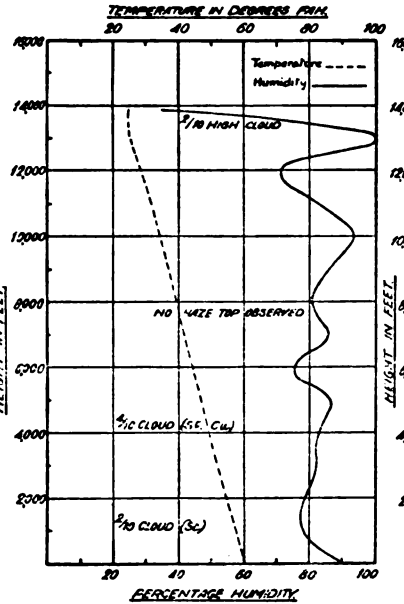

FIG 4 - TEMPERATURE AND HUMIDITY OF THE UPPER AIR ON JULY 31ST 1925. TIME 7 P.M. (S.T.)

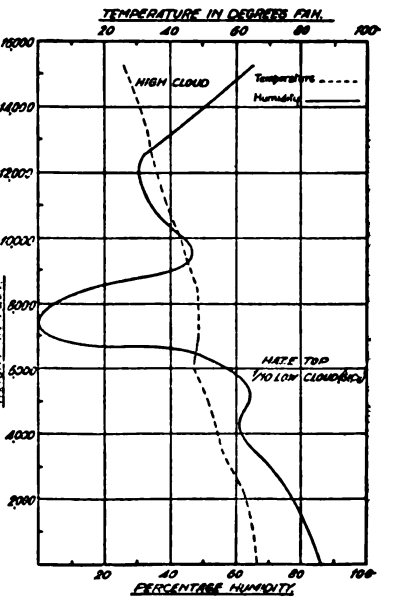

FIG 5 TEMPERATURE AND HUMIDITY OF THE UPPER AIR ON AUGUST 28TH 1925. TIME 7 P.M. (S.T.)

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Experimental flights by Vickers-Vimy aeroplanes took place shortly after readings of the upper air conditions had been obtained and observations were made of the aeroplane's sound by ear and instrument, so that it was possible to look for a relationship between the listening range and the meteorological conditions.

Variations of temperature and humidity of the upper air at different altitudes were shown graphically by charts, and four examples of these are given here (Figs. 2 to 5). The altitudes of the aeroplanes while flying for the experiments may be taken at from 5,000 to 9,000 feet. Meteorological conditions in regions higher than this can, therefore, be neglected, excepting when reflection from cloud or surfaces of separation might exist.

Fig. 2 (13th July) shows a very dry condition above 1,500 feet, where there commences a sharp drop of 50 per cent. in humidity; the temperature curve if compared with others of the same period appears unusual, there being two inversions which occurred at approximately 1,500 feet and 4,500 feet. The wind was adverse, but as the direction was constant and the velocity low it cannot be regarded as an important factor. (For particulars of wind see the accompanying table (Table II.) of wind speeds.)

TABLE II.—WIND SPEED AND DIRECTIONS, UPPER AIR, JULY 13TH, 28TH, 31ST, AND AUGUST 28TH.

Height in feet.	13th July. 8.35 p.m.		28th July. 8.30 p m.		31st July. 8 0 p.m.		28th August. 8.0 p.m.	
	Degrees.	m.p.h.	Degrees.	m p.h	Degrees.	m.p.h.	Degrees.	m.p.h.
Surface	046	9	245	15	360	6	238	12
1,000	107	13	247	29	351	15	260	23
2,000	090	11	275	21	020	16	273	14
3,000	061	13	273	21	341	16	274	16
4,000	063	18	275	27	333	15	270	13
5,000	055	15	273	35	315	13	262	12
6,000	049	15	273	39	301	16	—	—
7,000	039	15	275	37	293	24	—	—
8,000	040	17	271	32	287	28	—	—
9,000	027	15	270	33	284	27	—	—
10,000	013	11	275	39	—	—	—	—

On this occasion surface sounds were transmitted well, but from an altitude transmission was poor, the aeroplane note sounding muffled and indistinct. In one part of the machine's course—flown over several times—a definite silent zone was observed to exist. This is depicted in Fig. 6, the dotted lines representing silent sections of the courses and the full lines sections from which the machine was audible. The tracks were obtained by theodolite observations.

Fig. 3 (28th July) shows the average percentage of humidity to be moderately high, there being one stratum of dry air with increasing humidities above and below. The temperature curve was normal, the wind favourable, but becoming less so as the altitude increased.

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Sound transmission on the surface was moderate; from an altitude it was good, the note of the aeroplane being clear and distinct.

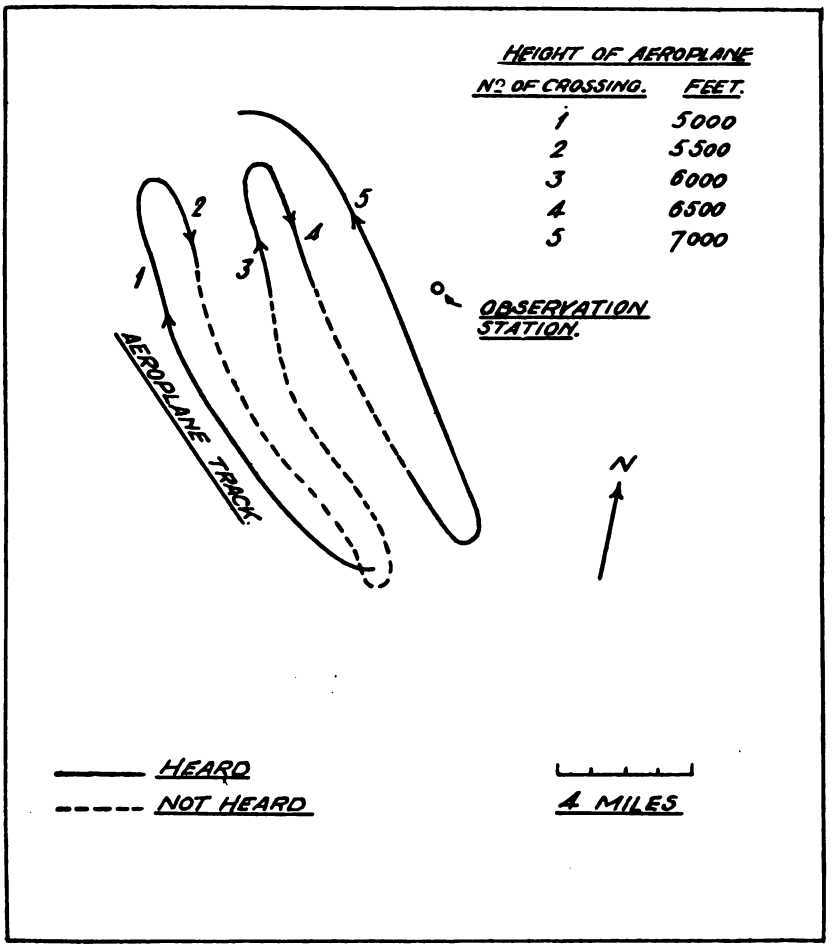

FIG. 6.- PLAN OF COURSE OF AEROPLANE ON JULY 13TH 1925.

Fig. 4 (31st July) shows a very high percentage of moisture, saturation point being reached at 13,000 feet, followed by a very sharp drop. The rate of fall of temperature was very constant. The wind was adverse near the surface, becoming a little more

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favourable as the altitude increased. This is a good example of an almost homogeneous atmosphere.

Sound transmission was exceptionally good, both on the surface and from an altitude. The note of the aeroplane was transmitted with greater clarity and intensity than on any other occasion, during the whole series of experimental flights.

Fig. 5 (28th August) shows high humidity up to the level of the haze top, 6,000 feet, then a rapid drop to the surprisingly dry condition of one per cent. relative humidity at 7,500 feet.[5] After a sharp rise the humidity remains on the low side. The temperature curve shows a slight inversion above which the temperature remains remarkably constant through those altitudes where exceedingly dry conditions prevail. The wind was favourable, but with a bad gradient above 1,000 feet.

Sound transmission was moderate on the surface but poor from an altitude. The aeroplane note was feeble, and the sound came through in bursts and was of a jerky nature throughout. This may have been caused through the path passing suddenly from dry to a wet atmosphere, or it may have been due to wind effect, for, as has been already pointed out, at 1,000 feet there was a sudden change from a good to a bad wind gradient.

Many peculiarities were observed which, no doubt, could be accounted for by meteorological conditions. For instance, during some flights the machine, when on the fringe of audible range, was alternately audible and inaudible; during others this effect was not present, the sound coming in suddenly and definitely. Again, beats (due to the two engines on the aeroplane running at different speeds) and changes of note as recorded by instrument were far more pronounced on some days than on others.

It was found that the changes from day to day of the form of the temperature curve were so small that the effects of temperature on sound arriving from an altitude may be regarded as nearly constant. It must be borne in mind, however, that we are considering observations made after sunset and that the problem of temperature would, doubtless, be far more complicated if dealt with during the heat of a summer's day.

The records show that the range of audible transmission was good on every occasion that the general humidity of the atmosphere at all levels was high, and usually, but not always, poor when it was low. At present, the data available are insufficient to allow any very definite interpretation to be put on this observation, but it may be surmised that a high general humidity is associated with

[5] Concerning the observations made on this date, Mr. Goodyear remarks "With reference to the meteorological data obtained during the ascent of August 28th last, there was undoubtedly a belt of exceptionally dry air between 6500 and 8500 feet. . . . There was an inversion above the haze top and the dry bulb remained constant at 49 degrees over a rise of 2000 feet while the wet bulb fell rapidly. I noticed this during the flight and so took readings every 500 feet instead of every 1000 feet in this dry layer, and I am quite certain that no error crept in. Almost equally low humidity readings were recorded on August 17th, cloud conditions being almost identical with those on the 28th. With regard to the 1 per cent. reading, when the air is exceedingly dry as in this case, the psychrometer will not give as accurate a result as with higher readings."

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a homogeneous condition of the atmosphere, while low humidity is associated with heterogeneity. This would account for the greater acoustical transparency which is generally found to occur when humidities are high.

The only factor in meteorological conditions whose changes are at all comparable with the great and sudden variations in the range of audible transmission is humidity,[6] and it therefore seems reasonable to look in this direction for some relationship.

Investigations following this line might throw light on the variations so often noticed in the character of the sound received. For instance, if when passing from one stratum to another there was a change in the amount of moisture in suspension sufficiently abrupt to form a surface of separation, sound would be deflected and the angle would, of course, vary as the source moved. This might be the explanation of sound coming through in bursts as it has often been observed to do. Again, a number of strata charged with different percentages of moisture would present media of different densities; therefore the direction of the rays would be subject to many changes, and this, probably, would give rise to sufficient refraction to cause indistinctness and distortion.

Before concluding, it may be said there seems little doubt that to obtain a more practical knowledge of the subject discussed it would be necessary to organise a series of flights during which careful observations of variations in the transmission of the aeroplane note were made concurrently with readings taken by an observer in the machine. It would be better if the times of such flights were determined, not by routine, but by conditions which offered a fair prospect of providing useful data. Again, while descending, readings should be taken at altitudes and in positions on the course approximately the same as those where readings were taken during ascent. We should then be able to form an estimate of the extent to which conditions vary over a given time.

With a greater amount of data provided by research on the lines indicated, a sufficiently intimate knowledge of the subject might be gained to enable us to predict, during any particular set of conditions, the range over which such a source of sound as an aeroplane would be audible. The solutions of the many problems involved would, no doubt, be led up to better by open-air experiments of a practical nature, followed by such laboratory research as the outside experience suggested, a procedure followed successfully by Tyndall in his research in a similar direction.

The work described in this paper was performed in the Acoustical Section of the Air Defence Experimental Establishment, Biggin Hill, Kent, with the help of the contribution made to the funds of that Section by the Department of Scientific and Industrial Research, on the recommendation of their Physics Research Board for work of civilian interest.

[6] Records given by a standard hair hygrograph, the clock of which had been converted so that the pen traversed in two and a quarter minutes the space on the chart allotted to two hours, have shown variations of as much as 15 per cent. in four and a half minutes, there being during this time no variation in temperature or apparent change in other conditions.

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DISCUSSION.

Mr. L. C. W. Bonacina said he quite agreed with the author's last remarks that acoustics were very suggestive. In regard to the seasonal aspect mentioned, he would like to remind Fellows of the paper read before the Society by Miller Christy a few years ago on observations of gun-firing on the continent during the war taken at Chigwell in Essex. These observations extended for four years, and in each one of these four consecutive years the long-distance firing was confined to the months of May, June, July and August, showing that there was some influence connected with the true summer period. What the explanation was it was very difficult to see, especially as he believed in other parts of Europe long-distance firing had been heard only at the opposite period of the year. In connection with long-distance firing at that time, it was observed (and he had noticed it himself when walking with a friend in the Weald of Sussex) that the firing from the continent was heard much more distinctly inside a wood than outside it. With regard to the reference to Prof. Tyndall, he thought Prof. Tyndall showed that sounds were more distinct during fog than in fair weather. He took it that the explanation was that fog occurred during these atmospheric conditions when sound was refracted downwards. Another reason might be that fog occurs when there is no wind or other extraneous influence to interfere with the sound.

Mr. C. J. P. Cave said he thought that the transmission of sound from great distances depended partly on the wind in the upper air. He was quite sure that in Hampshire the ideal occasion for hearing sounds of gun-firing in the Solent was when there was an Easterly wind with a reversal of direction above; under these conditions sound is refracted downwards and heard at great distances. On some occasions under these conditions the sound of firing at Spithead is heard twenty miles inland when actually in Southsea it was not possible to hear it at all. These conditions of wind are also the conditions in the summer when thunderstorms come up from the west, and long before he knew anything about meteorology he realised that if he heard the guns at Spithead very plainly in the summer, it was a very fair indication that thundery weather would come on.

The President (Sir Gilbert T. Walker) remarked that as liaison officer between the mathematician and the non-mathematician, he would like to point out the explanation of why sound goes with the wind. It is that sound travels along the quickest route: if a gun was fired in one place and the wind was blowing towards a second place, its velocity increasing with height, the quickest way for sound to travel from the gun to the second place was along a route raised in the air. If the wind was in the opposite direction, the quickest path was not up in the air, but along the surface of the ground. Therefore when the wind was blowing towards you, you heard from a great distance; it was a question of refraction. When there was dense air over the ground, the quickest road was into the warmer air and down again, and that was the reason why, with very cold air near the ground, you heard well; the converse of this was probably the explanation of the trouble the author of the paper had had on the thundery day when he did not hear well in either direction.

Mr. D. Brunt said he had been privileged to see the paper in its earlier stages and was therefore one of the few people who had been

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able to read it. He felt that Mr. Player had done a service in putting down on paper what were the facts which affected acoustics. If you sat down and tried to work out theoretically the acoustical problems discussed in this paper, you would find progress impossible, and the Acoustical Section had adopted the only wise plan in carrying on a long series of experiments. He did not think Mr. Player would claim that all the problems were solved, and perhaps meteorologists, when they read the paper, could give some assistance to the Acoustical Section. Some of the upper air temperatures and humidities given in the paper were curious, but apparently the observations were carried out very carefully by a meteorologist who was used to such work; therefore the results must be accepted.

Mr. E. S. PLAYER, in reply to the point raised by Mr. Bonacina referring to Prof. Tyndall's experience that sounds were more distinct during fog than fair weather, said that records had shown that much depended on the structure of the fog. If of a homogeneous nature, sound came through well, but fogs built up of banks of varying densities—or, in other words, patchy in structure—were most destructive to sound transmission. As regards downward refraction, that is when considering sound travelling over the sea's surface, this would probably depend on seasonal influences, which would hold good not only for fog, but other conditions of weather. The temperature of the sea during winter is normally above that of the earth's surface, and, especially with a wind off shore, would have a heating effect on the lower strata of the air, conditions which would be favourable to the production of a negative temperature gradient, the converse being the case during the summer months when the sea temperature is normally considerably lower than that of the earth. Nobody could say definitely what the effects of the many influences are, and a more perfect knowledge of these could only be obtained by using instruments for examining the conditions—especially those of the upper air—both at the source and the receiving station.

The question of sounds arising from explosions or gun-fire, especially when projectiles are used, although affected by the conditions influencing sounds from ordinary sources, involved additional problems which had no bearing on the latter, therefore it was somewhat difficult to draw comparisons. No doubt wind refraction played an important part, and this is borne out by the interesting observations of Mr. Cave. His experiences of sound coming through better during thundery conditions is parallel with the observations, quoted in the paper, of aeroplane notes being heard better during similar conditions, a point on which he thought the President had misunderstood him, probably owing to the remarks made in reference to oppressive days which one was naturally inclined to associate with thundery conditions. These conditions, however, do not always exist on such occasions.

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THE WET SUMMER OF 1924 AND OTHER WET SEASONS IN THE BRITISH ISLES.

By JOHN GLASSPOOLE, M.Sc., Ph.D.

[Received March 24—Read May 19, 1926.]

INTRODUCTION.

In a paper read before this Society in February, 1922,[1] some features of the remarkable drought of 1921 were discussed and compared with those of previous droughts in these islands. The abnormal rainfall of 1924 provided an opportunity for a similar study of pronounced wet seasons and this paper deals with the distribution of rainfall during wet seasons in the British Isles. The continuation of the second part of the joint paper on "The Drought of 1921," dealing with the associated pressure distributions, is represented in a paper by Mr. C. E. P. Brooks on "Pressure Distributions Associated with Wet Seasons in the British Isles."

Since the publication of the paper on the Drought of 1921, serial values, expressed as percentages of the averages, have been evaluated of monthly and of annual rainfall from 1870 to date. Greater precision has also been added to the results of this investigation by the use of a series of annual and of monthly maps. Annual maps for the period 1868 to 1923 are being published by this Society, while the preparation of the corresponding 600 monthly maps is being proceeded with. Such monthly maps as were required for the present paper were completed first.

THE RAINFALL OF THE YEAR 1924.

For the British Isles as a whole, the year was wetter than any since 1903. From 1868 to date there have been four wetter years, *viz.*, 1872, 1877, 1882 and 1903 with 137, 127, 120 and 127 per cent. compared with 117 per cent. of the average in 1924.[2] The distribution of the rainfall throughout the year presents features of a more remarkable character. After two months of widespread dryness, February and March, there was a succession of wet months from April to October inclusive, in each of which the general rainfall exceeded the respective average monthly fall. Attention has already been directed to some of the abnormalities of this wet period, of which the following may be mentioned:—[3]

[1] "The Drought of 1921," Brooks, C. E. P., and Glasspoole, J., *Q.J.R. Meteor. Soc.*, **48**, 1922, pp. 139-166.

[2] The average throughout this paper is for the period 1881 to 1915, whether for the year or for the individual months.

[3] The comparison of the rainfall of 1924 with earlier years is based on the serial values given in the article "General Monthly Rainfall over the British Isles 1881 to 1924," Glasspoole, J., *British Rainfall*, 1924, pp. 256-266. The general values for England and Wales, Scotland, Ireland and the British Isles separately have since been evaluated back to 1870, and are utilised in this paper. The general values are the means of the percentages of 53 stations evenly distributed over the British Isles. In order to obtain readily the general rainfall in actual inches these percentage values have been applied to the general averages. The accuracy of the method is discussed in *Q.J.R. Meteor. Soc.*, **41**, 1915, pp. 254-255.

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The two most remarkable months were May and September, with 187 and 182 per cent. of the respective averages for the British Isles as a whole. The rainfall of May exceeded that of every previous May since before 1870 and in a similar period the fall of September was only exceeded in September 1885, 1896 and 1918. The rainfall of the whole period, April to September, 1924, was for the whole British Isles, the largest in similar periods since before 1870, with the one exception of April to September, 1879, when about the same amount was recorded. The abnormality of 1924 is enhanced by October having 112 per cent. while October, 1879, received only 44 per cent. of the average. The general rainfall over the British Isles for the seven months April to October, 1924, of 30.7 inches was exceeded only once in similar periods back to 1870, when in 1903 the slightly larger total of 31.0 inches was reached. Thus the outstanding feature of the rainfall of 1924 is the sequence of seven months from April to October in each of which the fall exceeded the average.

The Rainfall of April to October, 1924.

A map showing the rainfall of the seven months, April to October, 1924, is given as Fig. 1. The map was prepared from data for about 53 evenly distributed stations—all the maps in this section were prepared in a similar manner, although in the earlier years slight changes in the stations were made. Much more information as to the rainfall of these periods is of course available, but while the inclusion of further data would possibly modify the lines locally, it may be taken that the general character of the maps on the scale as reproduced in the paper would not be appreciably altered.

The rainfall of April to October, 1924, was everywhere in the British Isles in excess of the average. Totals of less than 120 per cent. fell over a long tongue stretching from the north coast of Scotland to Ayrshire and including a large part of Central Scotland. Less than 120 per cent. also occurred in the neighbourhood of the River Humber. Less than 110 per cent. was experienced in a narrow strip along the north of Scotland. The fall exceeded 150 per cent. in the neightbourhood of Aberdeen and over large parts of the north-west of Ireland and of the south-west of England and Wales. The rainfall was mainly of the cyclonic type. It has been pointed out that the period of seven months with a rainfall most comparable with that of 1924 occurred in 1903. A map showing the rainfall of the period, April to October, 1903, is reproduced in Fig. 2. In this case the fall over the British Isles everywhere exceeded 110 per cent. of the average. The fall exceeded 150 per cent. in parts of Ross-shire, Yorkshire, and over a large area in the south and south-east of England and Wales. At Camden Square, London, the fall of 29.67 inches was 15.31 inches or 107 per cent. in excess of the average, compared with 23.27 inches or 62 per cent. in excess of the average for the similar period in 1924. In both periods the largest excesses occurred in the southern half of England and Wales.

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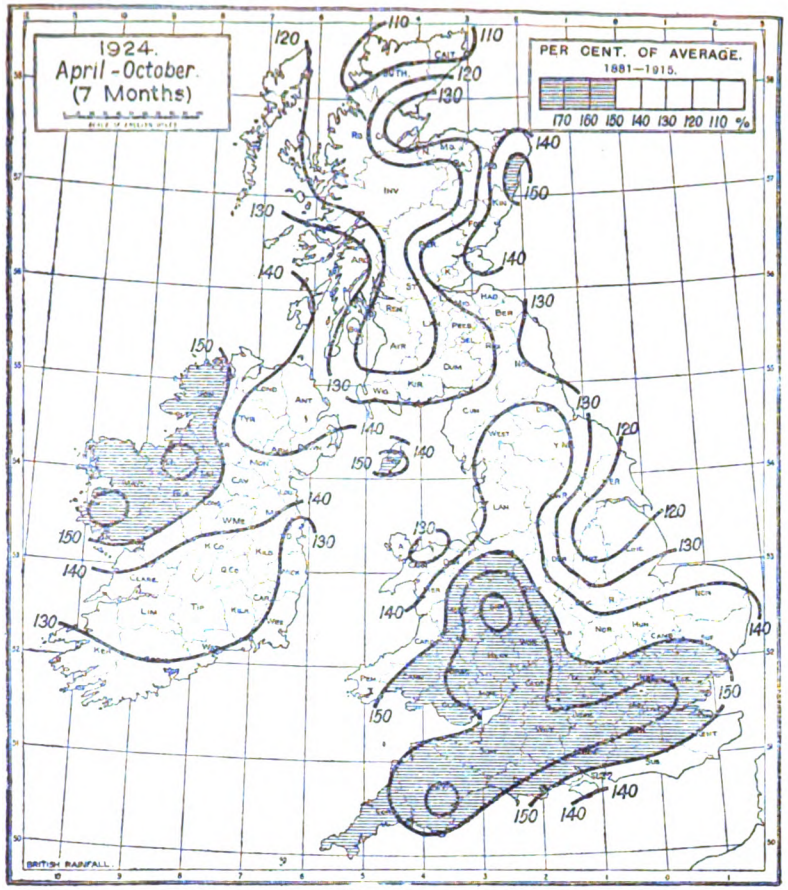

FIG. 1.

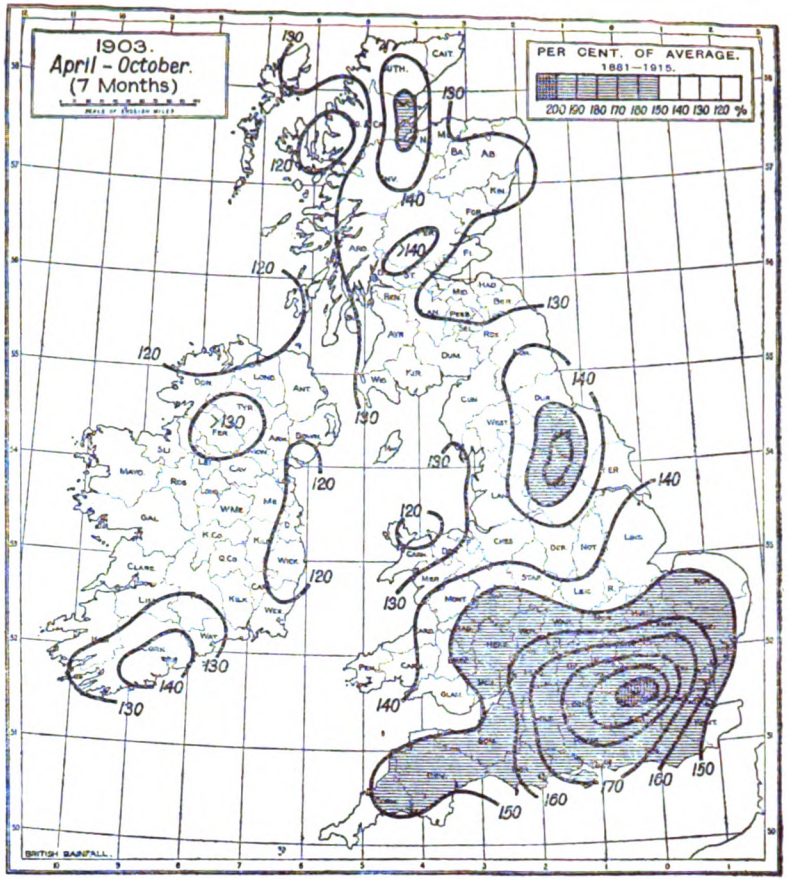

FIG. 2.

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Other Wet Seasons in the British Isles.

In selecting wet periods, reference was made to the table giving general values for each month back to 1870 for the British Isles (see footnote (3)). Only periods of three months' duration or more were considered. The longest sequence of consecutive months in which each month had a rainfall in excess of the average, for the British Isles, was generally adopted, even when a shorter period might have given more pronounced excesses.

Thus in 1903 the fall exceeded the average in the months, January to March and May to October, but in order to make a more direct comparison with the fall of 1924, April with 91 per cent. of the average, was included in the second group. It so happened that the three months, August to October, included in the seven months period of April to October, 1903, were much wetter than the three months January to March, 1903, but the rainfall of the three months August to October is not considered in detail as well as that of the longer period. In 1891 the general monthly percentage values for the British Isles, for the period August to December, were 169, 122, 141, 98 and 133. In this case the five-month period was adopted rather than the three month period. Groups of more than seven months were not considered. On only one occasion since 1870 was there more than this number of consecutive months in each of which the fall reached or exceeded the average, *viz.*, from September, 1876, to November, 1877, when the general fall for the fifteen months amounted to 137 per cent. of the average. For these fifteen months the most remarkable portion was the four months, November, 1876, to February, 1877, and the rainfall of these months is considered in detail.

For each of these groups, viz., of 3, 4, 5, 6 and 7 months duration the periods giving the largest general percentage values are set out in Table I., together with the general values for England and Wales, Scotland, Ireland and the British Isles. The table also indicates the periods for which maps are reproduced. General values are shown for the wettest periods in 1903 of 3 to 7 months' duration for comparison with the rainfall of similar periods in 1924. The table demonstrates that the most remarkable feature of the rainfall of 1924 was the persistent heavy rain spread over 5, 6 and 7 consecutive wet months.

It should be mentioned that the average general values for the individual months are not the same, so that percentage excesses in periods involving the wet months October, November and December, correspond to a larger quantity of rainfall than equal percentages for the dry months April, May and June. The general values for the individual months for the British Isles are set out below :—

General Monthly Averages. British Isles 1881 to 1915.

	in.		in.		in.		in.
Jan.	3.78	Apr.	2.52	July	3.25	Oct.	4.25
Feb.	3.26	May	2.61	Aug.	3.88	Nov.	4.19
Mar.	3.22	June	2.64	Sept.	3.09	Dec.	4.72

Year 41.41 inches.

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TABLE I.—Comparison of General Rainfall in 1924 with that of other Wet Periods of from 3 to 7 Months' Duration. Rainfall as Percentages of Average, for England and Wales, Scotland, Ireland, and the British Isles.

	Year	1924	1918	1913	1912	1907	1903	1903	1875
Period of 3 months	E. & W.	May-July 156	July-Sept. 162	Mar.-May.* 154	June-Aug.* 182	April-June.* 145	Jan.-Mar.* 126	Aug-Oct. 171	Sept.-Nov. 159
	S. . . .	140	139	138	123	148	169	155	120
	I. . . .	143	135	149	142	145	159	150	159
	B. I. . .	149	151	149	156	146	144	162	147
	Year	1924	...	1914-15	...	...	1903	...	1876-77
Period of 4 months	E. & W.	April-July. 152	...	Nov.-Feb.* 169	...	...	July-Oct. 163	...	Nov.-Feb.* 164
	S. . . .	129	...	136	...	...	155	...	143
	I. . . .	140	...	145	...	...	149	...	157
	B. I. . .	144	...	154	...	...	158	...	155
	Year	1924	...	...	1911-12	1903	1891	1876-77	1872-73
Period of 5 months	E. & W.	May-Sept. 149	...	...	Nov.-Mar.* 151	June-Oct. 156	Aug.-Dec.* 139	Sept.-Jan. 157	Sept.-Jan.* 152
	S. . . .	141	...	...	121	144	126	134	146
	I. . . .	150	...	...	134	139	129	168	160
	B. I. . .	147	...	...	139	150	133	152	152
	Year	1924	...	1919-20	...	...	1903	1882-83	1879
Period of 6 months	E. & W.	April-Sept. 147	...	Dec.-May.* 142	...	...	May.-Oct. 155	Sept.-Feb.* 139	April-Sept.* 159
	S. . . .	134	...	138	...	...	137	119	124
	I. . . .	147	...	138	...	...	133	132	138
	B. I. . .	144	...	139	...	...	146	131	144
	Year	1924	...	...	...	...	1903	...	1872
Period of 7 months	E. & W.	April-Oct.* 144	...	...	...	...	April-Oct.* 149	...	Jan.-July.* 146
	S. . . .	127	...	...	...	...	132	...	140
	I. . . .	139	...	...	...	...	126	...	127
	B. I. . .	138	...	...	...	...	140	...	140

* Maps are reproduced for these periods.

Since the present paper deals with questions relating to the departures from normal conditions, the relative wetness has been judged by percentage values rather than by the actual amount of rainfall.

December 1919 to May 1920 (Fig. 3).

General percentage values for the whole British Isles for the individual months were 147, 147, 106, 132, 162 and 148 respectively.

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The feature of the monthly rainfall maps of this period was the excess of rain in the west associated with a preponderance of westerly and south-westerly winds with a steep pressure gradient between the south and north of the British Isles, *i.e.*, the orographical type prevailed. In April, however, the numerous depressions, which in many cases followed abnormal tracks, were mainly responsible for the large excesses of rainfall in England and Wales, where over three times the average was recorded over a large area from Cheltenham in Gloucestershire to Lincoln in the north-east.

July to September, 1918.

The percentage values for the whole British Isles for the three months were 147, 83 and 242 per cent. respectively, so that September was mainly responsible for the large general value for the whole period of 151 per cent. The rainfall of July was dominated by thunderstorm rains in England and cyclonic rains in the east of Scotland. In September, cyclonic weather persisted throughout and the rain was of abnormal frequency. A map showing the fall of this month, as a percentage of the average, was given in *British Rainfall*, 1922, p. 239, and it was shown that September 1918 was the month with the largest percentage fall for the British Isles as a whole for any month on record. For the three months together the rainfall was below the average along a small part of the coast of Northumberland. More than 150 per cent. occurred over large areas, including about three-quarters of England and Wales, the greater part of the northern half of Scotland and part of the south-west of Ireland. The fall reached nearly twice the average in parts of the Counties of London, Devon, Wiltshire and Yorkshire W.R.

November 1914 to February 1915 (Fig. 4).

This period gives for the British Isles as a whole some of the largest totals of rainfall on record, *e.g.* :—

	General Rainfall (British Isles). ins.
Wettest Month, December 1914	8.6
Wettest two consecutive months, November-December 1914	13.9
Wettest three consecutive months, December 1914-February 1915	19.3
Wettest four consecutive months, November 1914-February 1915	24.6

The rainfall of the winter 1876 to 1877 gave some larger values, which are set out subsequently, and these are the only larger values in the series 1870 to 1925 inclusive. As a percentage of the average the general monthly values for the British Isles for the four months November 1914 to February 1915 were 127, 183, 127 and 181 respectively. The fall of the period November 1876 to February 1877 is shown in Table I. to be about equal to that of the similar period in the winter 1914 to 1915.

The rainfall of all four months was of the cyclonic type. Deficiencies were most widespread in January when the Central

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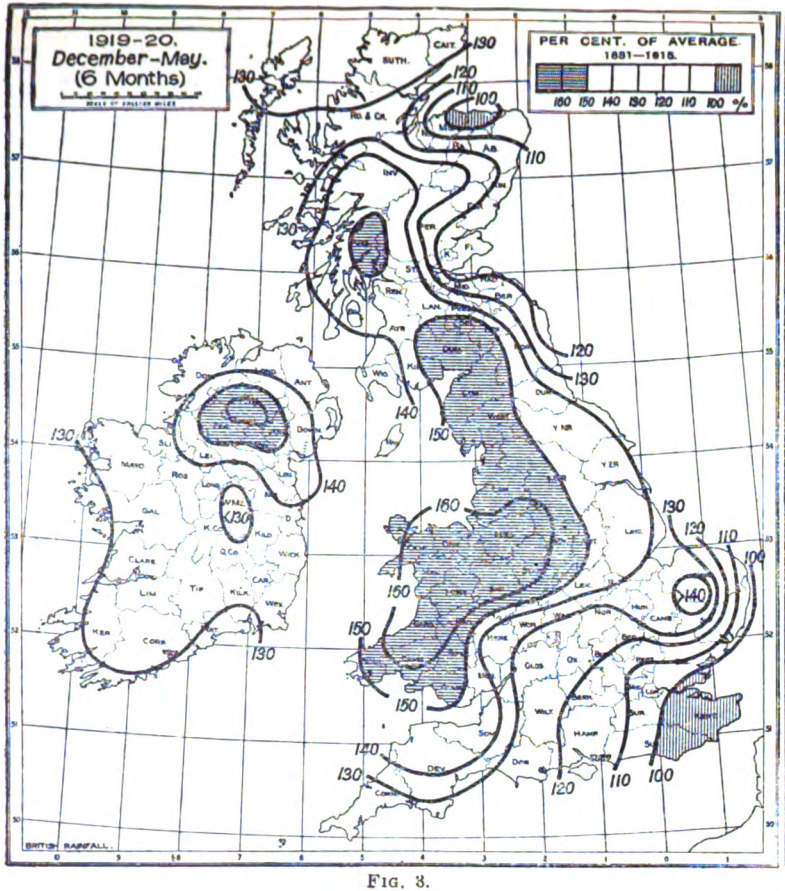

FIG. 3.

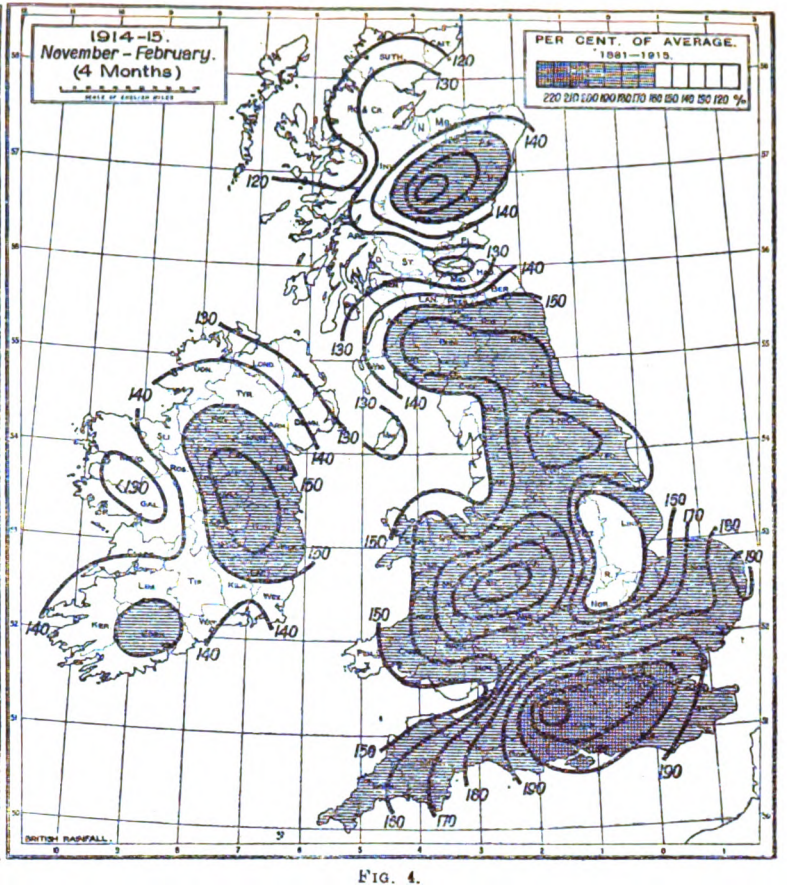

FIG. 4.

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Plain and south of Scotland were the largest areas so affected. In November deficiencies occurred along coastal strips, mainly in the south-west of England and Wales, of Scotland and of Ireland. In both December and February the fall over practically the whole of the British Isles exceeded the average, while more than twice the average fell over large areas equal in each case to about half the total area of the British Isles. The fall appears to have nowhere exceeded three times the average in any of these four months. A map showing the fall of the whole period is given in Fig. 4.

The available information, so far as England and Wales is concerned, is discussed in detail in a paper read before the Royal Meteorological Society in 1915,[4] when the conclusion was reached that " the rainfall of the four months, November 1914 to February 1915, over England and Wales as a whole was 0.71 in. greater than the rainfall of November 1876 to February 1877, or 6 per cent. greater, compared with the average, than the next wettest four months in any winter since the late G. J. Symons commenced the systematic collection of rainfall data." This conclusion is borne out by Table I. of this paper, which shows, in addition, that for the whole British Isles, November 1876 to February 1877 was somewhat wetter than the period November 1914 to February 1915.

March to May, 1913 (Fig. 5).

(General monthly percentage values 156, 163 and 126.)

In each month the least rainfall in relation to the average occurred along the east and north coasts of Great Britain and Ireland, the largest percentages being in the west and central regions. Falls exceeding twice the average were recorded in each of these months, the largest areas with this amount in both March and April included Central Wales and the bordering counties of England. The average general values for the whole British Isles for the 35 years 1881 to 1915 for the months of April and May are less than those for any other months. In actual inches of rainfall the value for March to May 1913 for the whole British Isles of 12.4 inches is not very remarkable, especially if it is compared with that of the three months December 1914 to February 1915 of 19.3 inches or of November 1876 to January 1877 of 21.0 inches. It will be recalled that the wet spring of 1913 was followed by a remarkably dry summer with the least rainfall over the British Isles as a whole in any July and August together since before 1864.[5]

June to August, 1912 (Fig. 6).

(General monthly percentage values 187, 114 and 172.)

In June a small area in the north of Scotland had less than the average. Falls of more than twice the average were widespread in all countries, the largest value being that of 302 per cent. recorded at Cardiff in Glamorganshire. In July less than the average

[4] " The Wet Winter of 1914-1915," Mill, D. H. R., and Carter, H. E., *Q.J.R. Meteor. Soc.*, **51**, 1915, pp. 253-282.

[5] " The Dry Summer of 1913," Mossman, R. C., *British Rainfall*, 1913, pp. 35-45.

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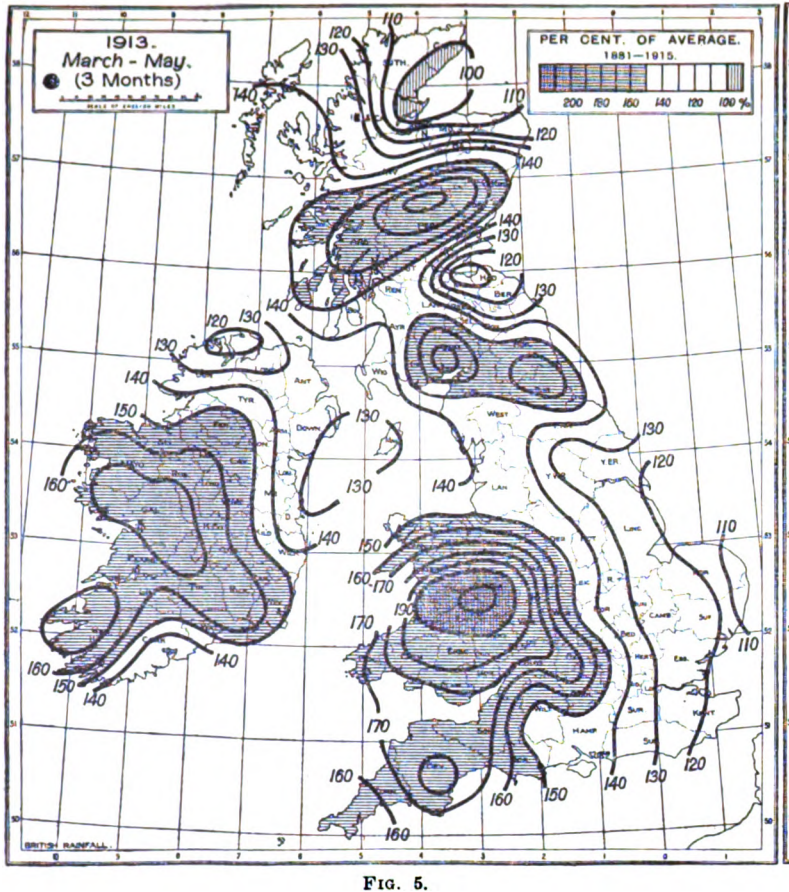

FIG. 5.

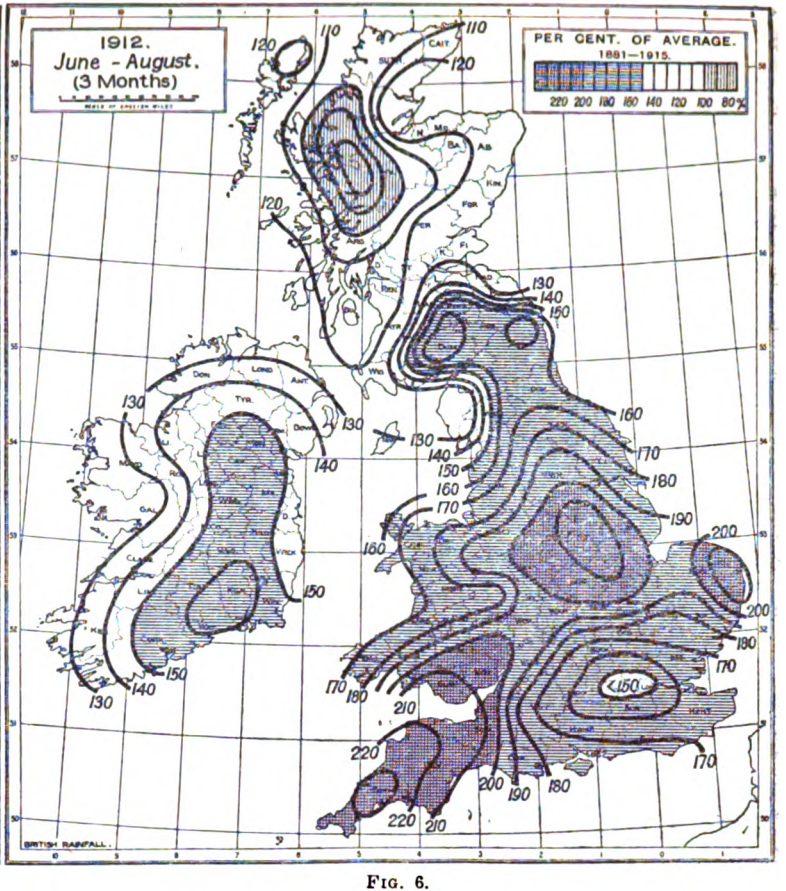

FIG. 6.

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occurred over practically the whole of Scotland, along the west and north coasts of Ireland and along the south coast of England. About twice the average occurred in the south of Ireland and in Nottinghamshire. In August, less than the average fell along coastal strips of the west of Scotland and Ireland, and only about half the average in the Western Highlands of Scotland. Falls of more than twice the average occurred in Sutherlandshire and south-east of a line drawn from Carmarthen to Grimsby. Within this wet area a band of still greater rainfall stretched from Cornwall to Norfolk, surpassing three times the average in three patches and exceeding four times the average in Norfolk on account of the storm of the 25th and 26th, when at Blofeld Road, Brundall, as much as 7.31 in. was recorded for the rainfall day of the 26th and 8.09 in. for the two days, the 25th and 26th.

The monthly rainfall maps of all three months belong to the cyclonic type of rainfall distribution. In June a series of shallow and slow-moving depressions, for the most part passing eastward and northward, dominated the weather of the month. In August the barometric conditions were very unusual and the number of depressions crossing the British Isles, especially the south of England, was extraordinarily large. The rainfall was most remarkable in England and Wales, and it was for that part of the kingdom, at any rate, the wettest August for at least half a century. For England and Wales the fall of this period, June to August 1912, of 182 per cent. is the largest, with that of 1879, in any such group of months since before 1870.[6]

It is probable that the fall for the three months, June to August, 1912, in the Brundall area reached 250 per cent. of the average.

November 1911 to March 1912 (Fig. 7).

(General monthly percentage values 135, 159, 127, 107 and 157.)

In each of these five months, less than the average occurred in the north-west of Scotland. In January and February such amounts were also recorded further south, *e.g.*, in the north-west of Ireland and the north-west of England and Wales. In March the deficiency extended along the east coast of Scotland. Each monthly map was therefore similar in the general distribution of dry and wet areas to that showing the rainfall of the whole period (Fig. 7).

November was a stormy month with the frequent passage of deep cyclonic systems, but it is interesting to note that none of the tracks crossed the central part of Great Britain between the Forth and the Wash. December 1911 was the wettest month, in actual inches of rainfall, since before 1870 with the two exceptions of October 1903 and December 1876, but the subsequent Decembers of 1914 and 1915 were somewhat wetter. The unsettled weather which characterised the whole of the winter of 1911 to 1912 was maintained to the end of March.

[6] "The Wettest Summer in England and Wales," Salter, Carle, *British Rainfall*, 1912, pp. 48-55.

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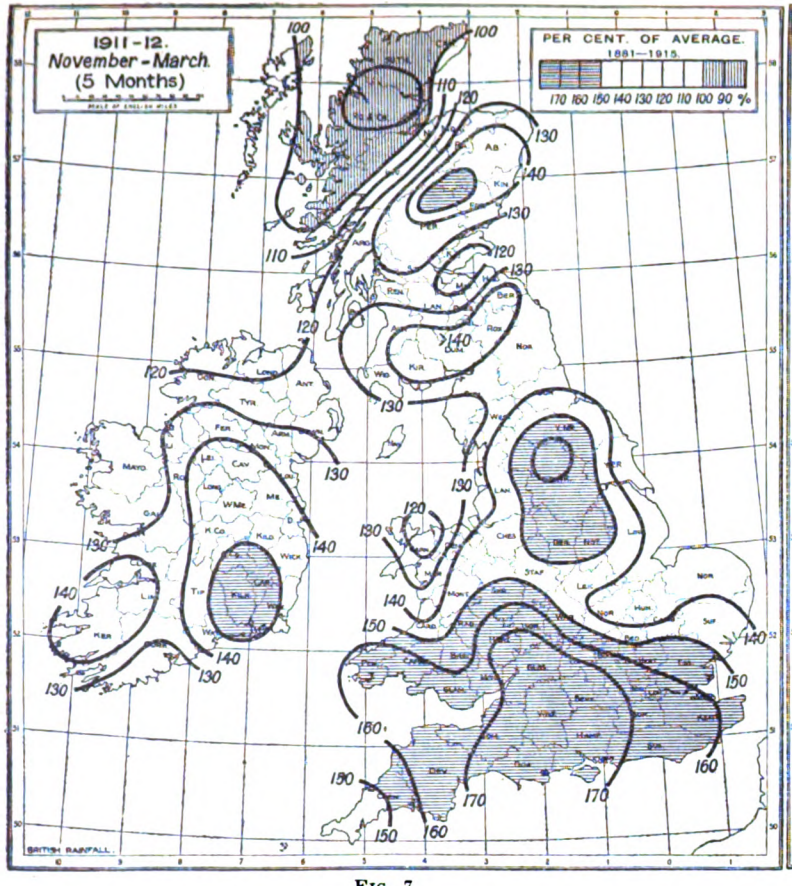

FIG. 7.

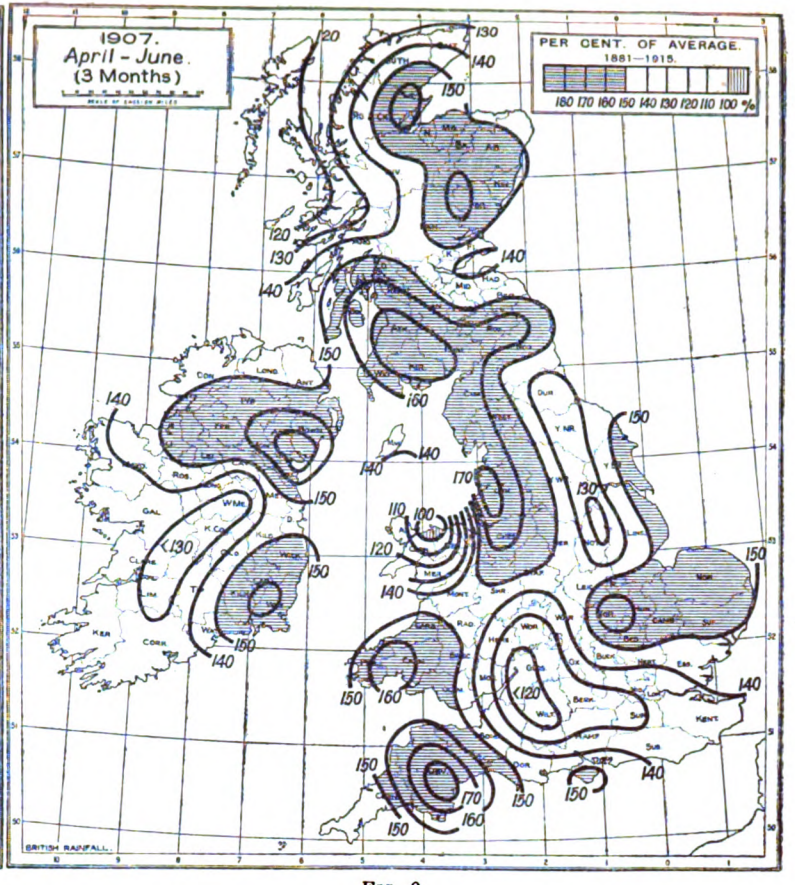

FIG. 8.

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APRIL TO JUNE, 1907 (FIG. 8).

(General monthly percentage values 125, 149 and 163.)

The main feature of the distribution of the rainfall over the British Isles during April was the large excess of rain in the south of England and Wales and also of Scotland with less than the average in the north of these two countries. The distribution in May was mainly of the easterly type with least rainfall in the north of Scotland. For June the distribution in England and Wales was of the westerly type, but in Scotland and Ireland, while there were excesses in the west, the largest values occurred in the north-west. Many observers, some with records extending over fifty years, reported that June was the darkest, coldest and wettest June ever known. For the British Isles as a whole, June 1907 was the wettest June since before 1870 with the two exceptions of 1879 and 1872. It was also exceeded by the subsequent June of 1912.

JANUARY TO MARCH, 1903 (FIG. 9).

(General monthly percentage values 146, 118 and 171.)

The fall for the whole period is shown in Table I. to be the largest in Scotland with 169 per cent. and the largest, together with the period September to November 1875, in Ireland. In all three months the orographical type of distribution prevailed and the largest excesses occurred in the western and north-western portions of the land masses. In January, less than the average fell along the east coast of England; in February, over the south-eastern half of England and Wales and along parts of the east coasts of Ireland; and in March, along parts of the east coasts of England and of Scotland. In January, more than twice the average fell over a broad strip between Edinburgh and Aberdeen. In February, more than twice the average occurred in the Western Highlands of Scotland, while in March such areas were much more widespread and included the greater part of Southern and Central Scotland, the English Lake District, Central and Northern Wales, and Central and Southern Ireland. In parts of Scotland, *e.g.*, in Kinross, Midlothian, Linlithgow and Fife, twice the average was recorded in each of the three months. The monthly total exceeded 10 inches in each of the three months January, February and March at more than 100 stations in the British Isles. Such records were found in the English Lake District, Central and Northern Wales, and in the Western Highlands of Scotland. At nearly all these stations more than one-third of the whole year's rainfall was recorded in the three months, even though it was a wet year. At Ben Nevis Observatory the totals for the three months were 33.45 in., 36.24 in. and 37.96 in. respectively, giving a total of 107.65 in. or 50 per cent. of the year's total, viz., 216.75 inches. March 1903 was by far the wettest March for the British Isles as a whole in the period 1870 to date.

APRIL TO OCTOBER, 1903 (FIG. 2).

(General monthly percentage values 91, 119, 102, 144, 147, 138 and 193.)

October was the most striking month, being for the British Isles as a whole the wettest October in the period 1870 to date,

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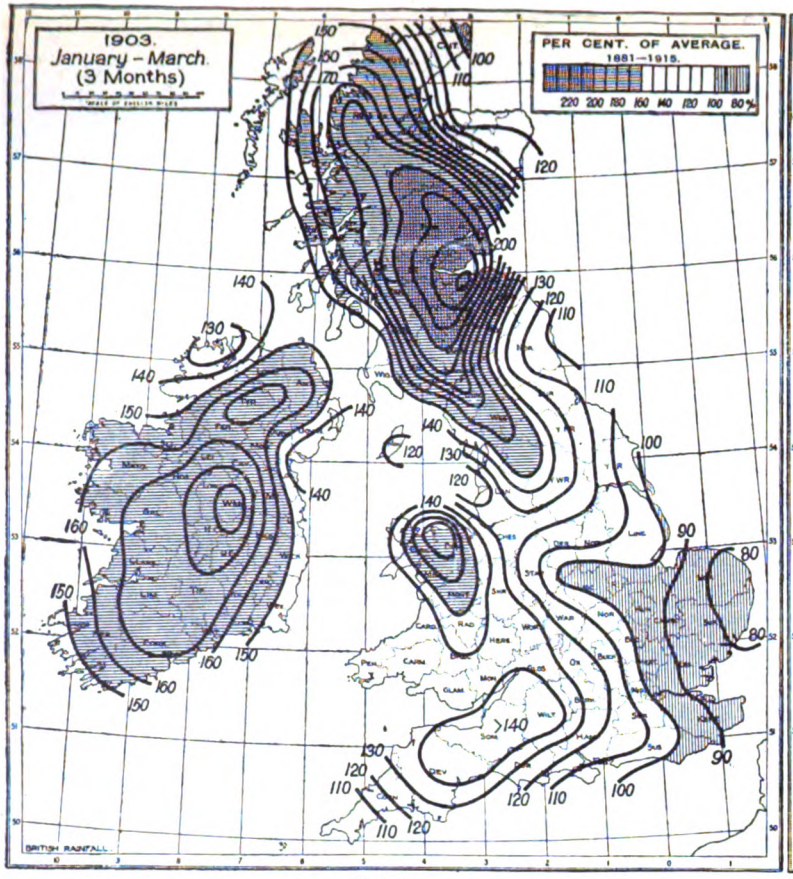

FIG. 9.

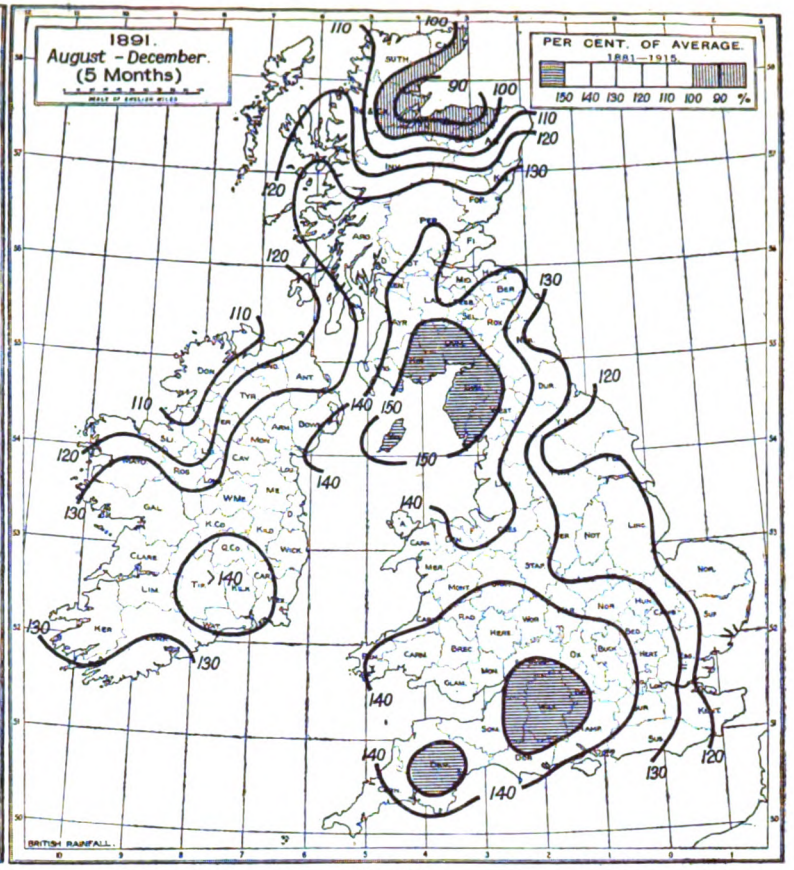

FIG. 10.

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and the wettest month in that period in actual inches with the two exceptions of December 1876 and December 1914. The rainfall of the three months of April, May and June was for the British Isles as a whole very nearly the average, but in all three monthly maps there was considerable variation and the largest excesses were in the south-east. In each of the months of July, August, September and October, the orographical type of distribution was fairly well developed, especially in August, although the usually dry regions, *e.g.*, the south-east of England, also experienced some large excesses. For London (Camden Square) the percentage monthly values for the whole period were 139, 170, 319, 218, 191, 145 and 229. The fall in June of 319 per cent. or 6.43 inches was the largest fall in June with the one exception of that of 1878 when 6.71 inches was recorded.

The succession of rain-bearing cyclones which swept our islands was continued in August, bringing weather of a most uncongenial type. For August, " wet and cold " was the burden of the remarks of observers from Land's End to John o' Groats, and from Slea Head to Lowestoft. The very heavy falls of October deserve some special mention. Falls exceeding 20 inches for the month were recorded at over thirty stations in the British Isles, representing large areas in the English Lake District, Central Wales and parts of Argyll and Stirling. At Clydach Reservoir near Mountain Ash, in Glamorganshire, the fall of 21.98 inches was as much as 22 per cent. of the year's total ot 99.67 inches.

August to December, 1891 (Fig. 10).

(General monthly percentage values 169, 122, 141, 98 and 133.)

The general type of distribution in the five months was mainly orographical. Less than the average occurred in August only in the Outer Hebrides; in September such values were more widespread and occurred over the south-eastern half of England and Wales, the north of Scotland and the north-west of Ireland; in October it was the eastern half of Scotland and the north-east of England; in November the north-western and south-eastern portions of the British Isles and in December the north-eastern part of Scotland.

The months individually were not remarkable for excessive rainfall except August, which gave the largest general percentage value for the whole British Isles in the series 1870 to date, with the exceptions of those of 1912 and 1917 with 172 and 183 respectively. It may be mentioned in passing that it was the preceding February, with 18 per cent., which was the driest month on record in the series for the British Isles as a whole.

Some remarkable floods occurred during the winter of 1891 in the Thames Valley, although the Thames rose considerably higher in November 1894.[7]

September 1882 to February 1883 (Fig. 11).

(General percentage values 118, 128, 140, 119, 133 and 155 respectively.)

In the maps showing the rainfall month by month, the cyclonic

[7] " November Floods of 1894 in Thames Valley," Symons, G. J., and Chatterton, G., *Q.J.R. Meteor. Soc.*, **21**, 1895, pp. 189-206.

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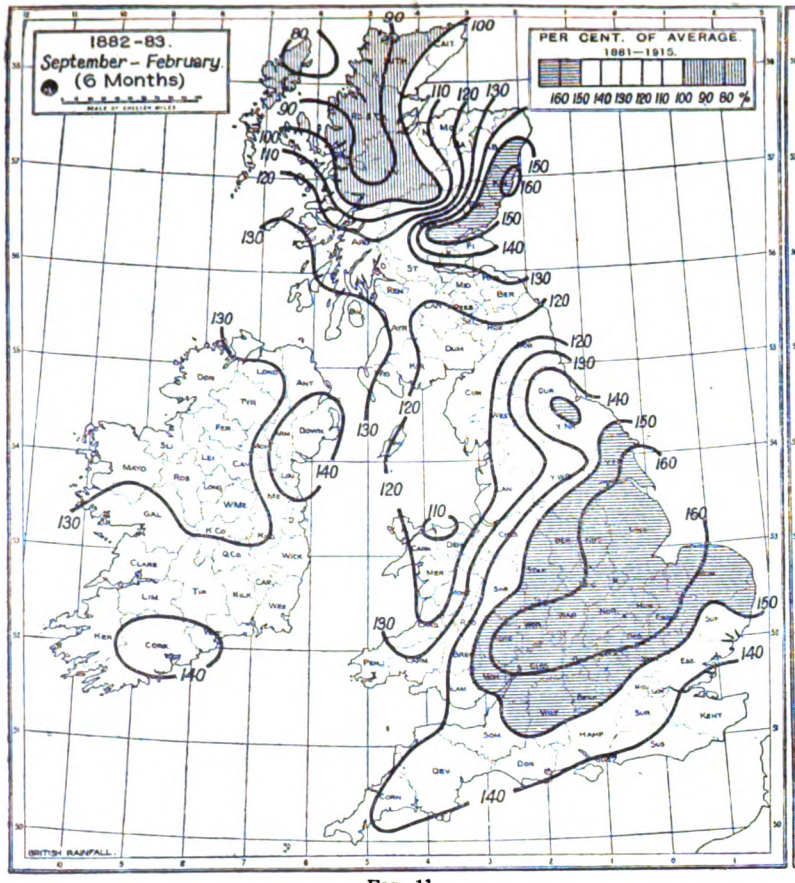

FIG. 11.

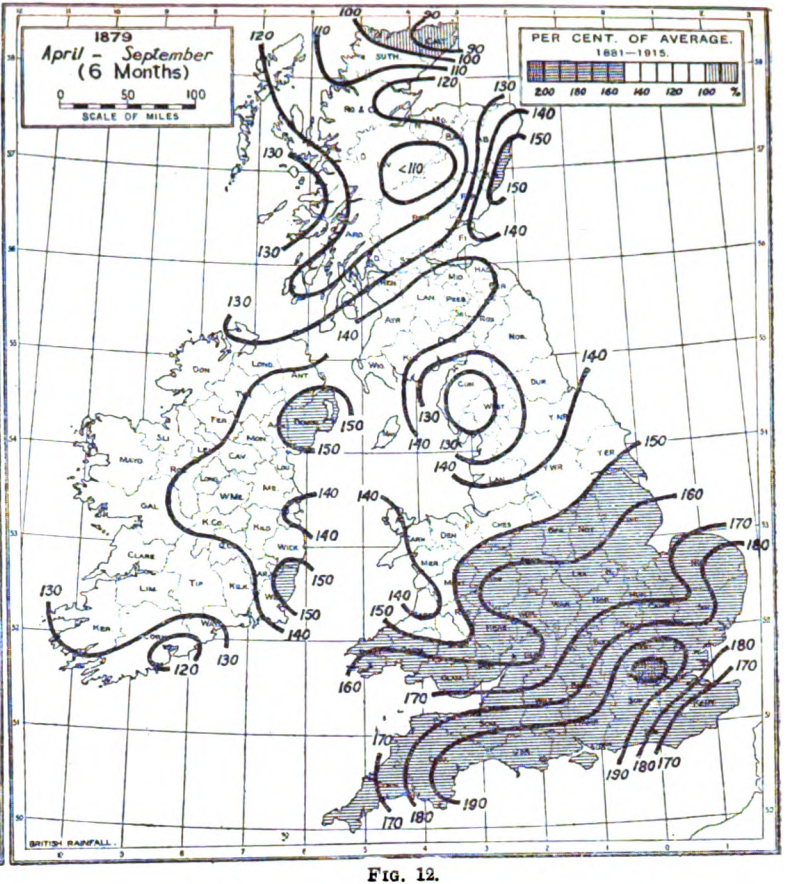

FIG. 12.

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type of distribution predominated with large excesses especially in the east. In September and October the largest excesses occurred in the south-east of England; in November in the north-west of Ireland, east coast of Scotland and Central England; in December, very definitely along the east coast of Great Britain; while in January such areas were not well-defined but included parts of the south of Ireland and west of England, and in February the south of England, south-west of Ireland and north-east of Scotland.

WET SEASONS IN THE 'SEVENTIES.

The abnormal wetness during the 'seventies, and the lack of comparative statistics of the rainfall of these early years, renders a consideration of the rainfall of particular importance. For the British Isles as a whole, 1872 and 1877, with 137 and 127 per cent. respectively, were among the three wettest years in the series 1868 to 1925, the value for the other year, viz., 1903, being 127 per cent. In a recent paper[8] it is shown that over as much as half of the total area of the British Isles, the rainfall of 1872 was not exceeded in any year since comparative statistics became available in 1868. Until the present paper, little was known of the relative wetness of these early months. A mass of data was of course available, but the descriptions given in the corresponding volumes of *British Rainfall* can now be elaborated. There, June 1879 is described as "a wet month." It can now be described as the wettest June in 55 years' observations with 196 per cent. of the average. July 1879 is referred to as "another wet month." With 151 per cent. of the July average, it was the wettest July in the series with two exceptions. In both cases maps are now available giving the rainfall distribution as a percentage of the average 1881 to 1915. Reference has already been made to the run of fifteen months from September 1876 to November 1877, in each of which the general fall for the British Isles reached or exceeded the average, viz., 171, 100, 118, 189, 192, 117, 103, 149, 128, 123, 131, 149, 103, 117 and 155 per cent. This period provided the wettest months in actual inches of rainfall in the period 1870 to date, viz. :—

	General Rainfall (British Isles) ins.
Wettest month, December 1876	8.9
Wettest two consecutive months, December 1876-January 1877	16.1
Wettest three consecutive months, November 1876-January 1877	21.0
Wettest four consecutive months, October 1876-January 1877	25.2

It will be noticed that the two wettest months given above were as much as 2.2 inches wetter than the next two wettest months, November to December 1914.

The rainfall of the four months November 1876 to February 1877 is considered in detail. The rainfall of the wettest year 1872 is considered in two parts, viz., January to July 1872 and September

[8] "The Driest and Wettest Years at Individual Stations in the British Isles, 1868-1924," Glasspoole, J., *Q.J.R. Meteor. Soc.*, **52**, 1926, pp. 237-248.

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1872 to January 1873. This excludes August, a month in which the rainfall was just under the average. Two other periods call for special mention, viz., April to September 1879 and September to November 1875.

April to September, 1879 (Fig. 12).

(General monthly percentage values 109, 114, 196, 151, 147 and 143.)

June 1879 was the wettest June in England and Wales, in Ireland and in the British Isles as a whole, but the fall in Scotland was exceeded on eight occasions. The general percentage values were England and Wales 213, Scotland 150, Ireland 224 and British Isles 196.

The fall for the whole period was mainly of the cyclonic type, the largest excesses occurring in the south-eastern half of England and along the east coast of Scotland and of Ireland. In these districts the fall exceeded 150 per cent. of the average. At Camden Square, London, the fall of the six summer months was rather more than twice the average of that period, reaching 23.89 inches or only .58 inch short of the average for the whole year. The fall was less than the average only in the north-east of Scotland.

The main feature of the monthly rainfall maps was the steep gradient between the south-east of England and the north-west of Scotland. In April small areas in the neighbourhood of the Isle of Wight and Northampton received more than twice the average, while less than 50 per cent. occurred along the north-west coast of Scotland. In May the gradient was less well-marked, the areas with excesses in the case of Scotland and of Ireland being in the north-east instead of the south. More than twice the average occurred at Tenterden in Kent. Large areas received more than twice the average in June. This occurred over practically the whole of Ireland, over the Southern Uplands of Scotland and the Cheviots, and over the south-west of England and Wales. In the Devon-Cornwall peninsula more than three times the average fell over a large area, while at Druid House, Ashburton, near Dartmoor, as much as 11.30 inches or 442 per cent. of the average was recorded. In July the excesses were less pronounced and fairly uniformly distributed over the British Isles. The gradient was maintained in August when more than twice the average fell over a large area between Worcester, London and the Isle of Wight, and less than the average in the Western Highlands of Scotland and north of Ireland. In September there was the same type of distribution so far as England and Wales was concerned, but in Scotland parts of the west coast received more than twice the average while the east coast was generally dry.

November 1876 to February 1877 (Fig. 13).

The map showing the distribution of rainfall for the period November 1876 to February 1877 is conspicuous for the steep rainfall gradient from the east to the west. In Ireland the percentage fall varied from 192 per cent. at Greenore, in Co. Louth, to 116 per cent. at Nenagh, in Co. Clare; while in Scotland the gradient was even steeper, viz., from 250 per cent. at Marchmont

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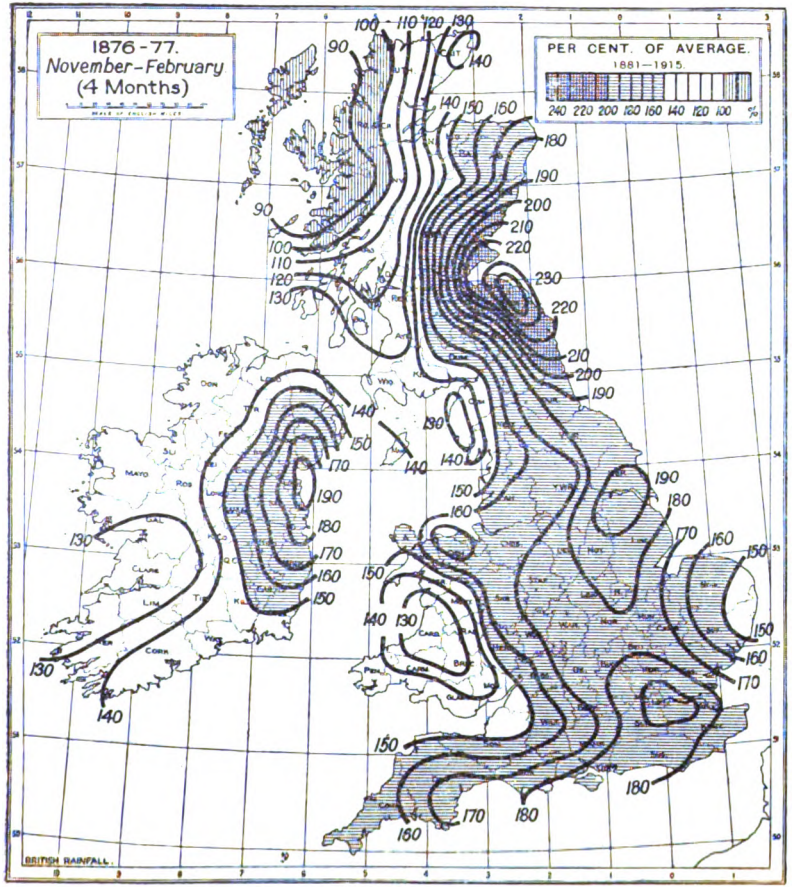

FIG. 13.

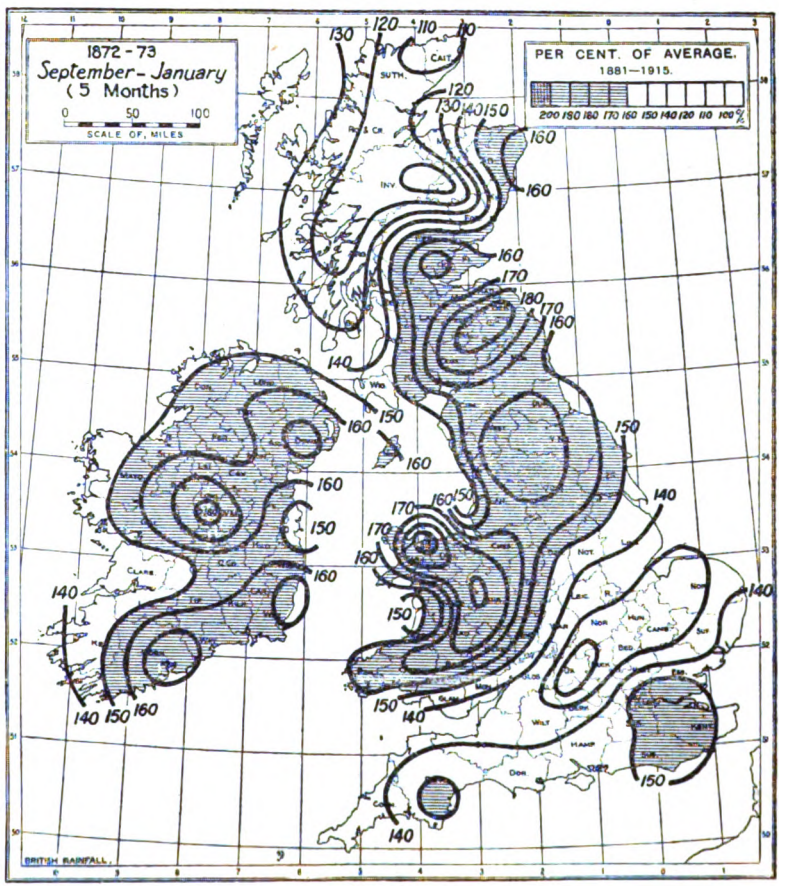

FIG. 14.

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House in Berwickshire to 81 per cent. in the Isle of Mull. In England and Wales rather more than 190 per cent. occurred round the mouth of the Humber and near London. Less than 150 per cent. occurred on either side of this ridge of high rainfall, viz., along the coast of Norfolk and Suffolk and over the greater part of Southern and Central Wales.

The most remarkable months in the run of wet months of 1876 to 1877 were September and December 1876 and January 1877. Both December and January were the wettest month of those names in the series under discussion, and the consecutive occurrence of these two extreme months was largely responsible for the abnormality of this period. It will be noticed in Table I. that the values for Ireland for the four months November 1876 to February 1877 and for the five months September 1876 to January 1877 are larger than those for the other groups of four and five months respectively. The rainfall of November 1876 and February 1877, 118 and 117 per cent. respectively, was of the cyclonic type, but the excesses were nowhere of a remarkable character. The maps for December 1876 and January 1877 are similar in that in both cases the rainfall in the north-west of Scotland was below the average. In December more than twice the average occurred mainly along the east coast of Great Britain and of Ireland. Three times the average occurred in the neighbourhood of Dublin and over a large area from Edinburgh to Durham. The largest percentage fall was that of 406 per cent. at Marchmont House in Berwickshire, when the fall of 11.42 inches or 35 per cent. of the annual average was the largest monthly total on record at that station, where observations commenced in 1867. The gradient in this month, from four times the average in the east of Scotland to less than half the average in the Western Highlands of Scotland is extremely remarkable. The distribution of the rainfall in this month can be regarded as one of the best examples of the east coast type. Upon the whole, south and south-westerly winds predominated over the southern half of the country and south-easterly and easterly winds over the northern portion. The main features of the depressions were that they were both numerous and deep, and in nearly every case followed a northerly or north-easterly path. The direction of the cyclones is probably the cause of the main difference between the cyclonic and easterly type of rainfall distribution.

In January 1877 areas with more than twice the average were irregularly distributed. These appear to radiate from the Isle of Man in three main directions covering north-eastern Ireland, parts of south and eastern Scotland and a broad tract to the east of Wales stretching from the north-west coast of England to the mouth of the Thames and to the Devon-Cornwall peninsula. More than three times the average occurred in the Isle of Man, in Co. Down, at Edinburgh and at Tenterden in Kent.

September to November 1875.

(General monthly percentage values 160, 143 and 142.)

A feature common to the three monthly maps was an area of deficient rainfall in the north-west of Scotland. In September it

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stretched from Sutherlandshire to the Isle of Islay. It reached in October as far south as the English Lake District and as far east as Edinburgh and Keith. The area was very similar in November except that it did not stretch as far east. In October and November there was also an area of deficient rainfall to the west of Ireland. In all three months considerable areas received more than twice the average, especially in the south and south-east of Ireland in September and October, and in central and eastern England in October and November. The rainfall of the three months September to November 1875 was most remarkable in Ireland, where the general fall of 159 per cent. of the average is the largest value, with that for January to March 1903, in Table I. for groups of three months. As the general rainfall over the British Isles was exceeded on a number of occasions, a map is not reproduced for the rainfall of this period.

September 1872 to January 1873 (Fig. 14).

(General monthly percentage values 171, 145, 153, 142 and 153.)

The main feature of this period was the sequence of wet months rather than the abnormal wetness of any individual month.

The rainfall map of this period is of the cyclonic type and presents the somewhat unusual feature of a ridge of high rainfall lying across the central portion of the British Isles in a south-west to north-east direction with smaller excesses to the north-west and south-east. More than 150 per cent. occurred over a broad belt between Galway and Aberdeen on the north-west and Swansea and Hull on the south-east. Twice the average was recorded at Llandudno and Marchmont House in Berwickshire. Less than 120 per cent. of the average occurred in Oxfordshire and over a large area from Inverness-shire to Caithness.

Less than the average occurred in the south-east of England in September only, and in the north of Scotland in November and December 1872 and in January 1873. More than twice the average was somewhere recorded in each month, but such areas were widespread only in September when they included the north-west of Ireland and a wide coastal strip from Nairn to Hull stretching across to North Wales.

Among the large figures for this period may be mentioned the fall of 10.44 inches in November at Dover or about 310 per cent. of the average, and the fall of 31.70 inches or about 290 per cent. of the average at the wetter station Bridge of Orchy, near Dalmally, in Argyllshire, in January 1873.

January to July 1872.

(General monthly percentage values 181, 135, 115, 112, 109, 188 and 135.)

The distribution of the rainfall of this period was in general similar to that for the period September 1872 to January 1873. More than 150 per cent. occurred over a broad belt across England and Wales from Dartmoor to the Yorkshire moors, and in Scotland from Dumfries to Braemar in Aberdeenshire as well as in the Outer Hebrides. Less than 120 per cent. was recorded at Kent, over

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the western and central portion of Ireland and over a belt from Fort William to Caithness.

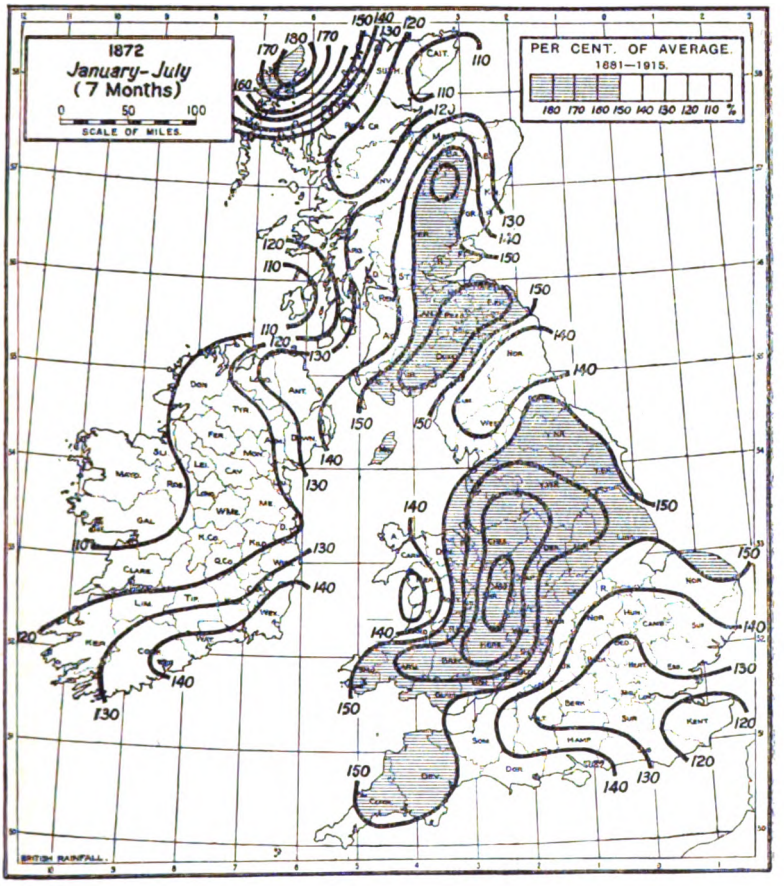

FIG. 15.

The main features of the monthly maps may be briefly set out:—In January there were large areas with more than twice the average in the south of England from Land's End to Margate, the English Lake District and Southern Uplands of Scotland. As much as 50.05 in. was recorded for the month at The Stye, Borrowdale, in Cumberland. In February, twice the average occurred only in small areas, but less than the average was widespread in the south-east of England and north of Scotland. More than the average in March was experienced over nearly all the country to the south-east of a fairly well-marked line from Killarney to Dundee. Less than half of the average in April occurred in the south-west of Ireland and of Scotland, and twice the average in Yorkshire and Shropshire. In May, less than the average was recorded over practically the whole of Ireland, the south-west of

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Scotland and north-western half of England and Wales. The rainfall was everywhere above the average in June, twice the average being exceeded over practically the whole of Scotland and along the north-west coast of England and Wales. In July, less than half the average occurred in the neighbourhood of Dublin and in the Isle of Islay. More than twice the average fell over a broad belt from Hull to Southport and locally in the neighbourhood of the Isle of Wight, Gloucester, Bury St. Edmunds and Cork.

Summary and Conclusions.

1. *Classification of Maps of Wet Periods.*

In dealing with the percentage maps of annual rainfall a classification was adopted in an earlier paper, according to the preponderance of rain :—[9]

(1) In the west (orographical),
(2) In the east (non-orographical), and
(3) In some other centre (cyclonic).

This classification was adopted in the present paper. Classes (2) and (3) tend to merge into one another and type (1) is usually less well-developed than the other two types, since a fall in the wet areas of the west corresponds to a much smaller percentage than a similar fall in the drier areas of the east and south.

TABLE II. Rainfall Classification, British Isles.

Mainly Orographical.	Mainly Non-orographical.	Mainly Cyclonic.
Dec. 1919-May 1920	Nov. 1876–Feb. 1877	April-October 1924
March-May 1913		July-September 1918
April-June 1907		Nov. 1914-Feb. 1915
January-March 1903		June-August 1912
August-December 1891		Nov. 1911-March 1912
		April-October 1903
		Sept. 1882-Feb. 1883
		April-September 1879
		Sept.-Nov. 1875
		Sept. 1872-Jan. 1873
		Jan.-July 1872

It will be seen that in each class the type of distribution does not extend over the whole of the British Isles and that the maps of each class have as many points of dissimilarity as of resemblance. This difficulty is experienced whether the series of percentage maps are for the month, year, or for any other period. Some attempt has been made to classify annual maps,[9] and it is hoped to continue this with the monthly maps.

In comparing the maps of the paper on "The Drought of 1921" with those for wet periods, it is apparent that while large deficiencies are confined mainly to the south and east of the British Isles, large excesses do occur in the north and west. Thus in

[9] "The Fluctuations of Annual Rainfall in the British Isles considered Cartographically," Salter, Carle, and Glasspoole, J., *Q.J.R. Meteor. Soc.*, **49**, 1923, p. 213.

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January to March 1903 there were large excesses in the north, and in December 1919 to May 1920 large excesses in the west. In the "Drought Paper" there were no instances where the largest departures occurred either in the north or west.

The question of fluctuations in general has been considered in some detail in "The Fluctuations of Annual Rainfall"[10] and in "Fluctuations of Monthly Rainfall."[11] In these papers all the percentage fluctuations, whether excesses or deficiencies, over a long period were considered and the areas where the fluctuations were large or small defined. The question of the fluctuations of rainfall over the British Isles has been carried a stage further in this paper, by considering the extreme conditions of wetness of periods of three to seven months' duration.

The object of the present section has been to obtain more precise information concerning wet periods over the British Isles. The results give a basis of comparison for current weather and an indication of that likely to be experienced in the future. The wettest periods have been selected so that the accompanying pressure and other meteorological conditions over the British Isles and Western Europe generally can be considered in relation to the rainfall.

The final copies of the maps included in this paper were prepared by Mr. A. T. Bench, to whom my thanks are due.

DISCUSSION.

Mr. L. C. W. BONACINA said he was glad Dr. Glasspoole had referred to conditions on both sides of the Irish Sea, because it was a curious feature that the normal rainfall on both sides had a maximum in August and he had never quite been able to see why. The Irish Sea forms a sort of climatic unit in this respect.

The PRESIDENT (Sir Gilbert T. Walker) pointed out that one of the reasons why the regions of heaviest rainfall tend to be ignored in general inquiries was that in discussing the rainfall of a country, it did not much matter from the administrative point of view what happened in the wild mountainous regions; it was information about the agricultural regions below that was of great importance.

Mr. A. PEARSE JENKIN suggested that in an area having a length from north to south of some 500 miles, with the centres of many depressions crossing this area from west to east, conditions in the north would be likely to neutralise those in the south. Similarly, from orographical reasons, conditions in the east might be very different from those in the west; so that better results would be obtained, for purposes of comparison, by taking separately north and south districts, and also east and west.

Dr. GLASSPOOLE, in reply, referred to the advantages of dealing with maps showing the rainfall as a percentage of the average rather than in actual inches. The disadvantage in comparing maps in which the rainfall is shown by isohyetal lines is that such maps are more intricate than the percentage maps, the isohyetal lines following the configuration of the land and each map being consequently similar. The percentage maps bring out clearly the variations from the average state of affairs.

[10] Glasspoole, J., *British Rainfall*, 1921, pp. 288-300.
[11] Glasspoole, J., *British Rainfall*, 1922, pp. 234-259.

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Another important point in considering maps of actual rainfall is that in drawing the lines, estimates must be made for the mountain areas where no records are available. More information is being accumulated about the distribution of annual average rainfall over these regions and such maps are therefore becoming even more intricate.

The Earthquake of August 15th, 1926.

Although earthquake shocks are not frequent in the British Isles, the disturbance on August 15 represents the fourth which has occurred this year. Other tremors have been centred near Comrie, Perthshire (February 21), Aberdare (April 12) and Jersey (July 30). The recent shock has evoked considerable attention on account of its wide distribution. It was registered on the seismographs at Kew Observatory, Richmond, and some data which have been extracted from the instrumental records may be of interest.

The first preliminary tremors reached Kew at 3h. 58m. 48s. G.M.T. and the secondary phase appeared at 3h. 59m. 9s., the whole disturbance from start to finish lasting only three minutes. From these times the distance of origin from the Observatory is deduced as 190 km. (120 miles). This distance agrees very well with the reports giving Ludlow and the neighbouring villages as the district which was most severely shaken. It is noteworthy, too, that the centre of the area over which the earthquake was felt lies in this district. The time of the commencement of the disturbance at the origin is deduced as 3h. 58m. 19s., and on the whole the estimates of the time of occurrence given by persons who felt the shock near the origin are surprisingly good. The fact that the shock occurred at very nearly an exact hour and that therefore many observers heard clocks striking may account for this accuracy; but it is suggested that it may in part be due to the fact that wide use is now being made of broadcast time-signals.

The determination of the actual amount of movement of the earth due to the major shock presents some difficulties, but an approximate calculation of the movement which took place at Kew has been attempted and the amount has been found to be of the order of one-tenth of a millimetre (1/250in.). At first sight the magnitude of this movement of the earth's crust may appear so small as to be negligible, but it was sufficient to rattle windows and crockery and even disturb people asleep in their beds. There is, however, on this account no need for alarm, as no shock of greater intensity is likely to occur in this country. And as a matter of fact, the sensations produced on people living in the most highly disturbed area were no more serious than those produced on occupants of houses on main roads during the passage of a heavy traction engine on a bad stretch of the road.

The whole district shaken is a nearly circular area, about 270 miles in diameter, and containing, therefore, about 60,000 square miles. It is almost certain that the recent shock was due to movement of the earth along the Hereford fault. Several earthquakes which have occurred in the British Isles within the last forty or fifty years have been attributed to the same cause; in fact, the recent one bears a very strong resemblance to one which took place in 1868, particularly as regards intensity and disturbed area.

F. J. SCRASE.

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PRESSURE DISTRIBUTIONS ASSOCIATED WITH WET SEASONS IN THE BRITISH ISLES.

By C. E. P. BROOKS, M.Sc.

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The second part of the paper on the drought of 1921[1] contained a discussion of the distribution of pressure (deviation from normal) associated with a number of marked droughts in the British Isles. The present paper contains a similar discussion of the pressure distributions associated with a number of the wet seasons analysed by Dr. J. Glasspoole in his paper on "The Wet Summer of 1924 and other wet seasons in the British Isles." Charts have been prepared showing the deviation of pressure from normal over the northern hemisphere during each of the following periods:

April to October, 1924	Fig. 1.
December, 1919 to May, 1920	Fig. 2.
July to September, 1918	Fig. 3.
November, 1914 to February, 1915	Fig. 4.
March to May, 1913	Fig. 5.
June to August, 1912	Fig. 6.
November, 1911 to March, 1912	Fig. 7.
April to June, 1907	Fig. 8.
January to March, 1903	Fig. 9.
April to October, 1903	Fig. 10.
August to December, 1891	Fig. 11.
September, 1882 to February, 1883	Fig. 12.
April to September, 1879	Fig. 13.
November, 1876 to February, 1877	Fig. 14.

The notes as to the distribution of rainfall over the British Isles refer to the data given in Dr. Glasspoole's paper.

April to October, 1924.

The chart shows a deficit of pressure over the British Isles, exceeding 5 mb. over most of Scotland. Pressure was also slightly below normal over Scandinavia, Spitsbergen, Iceland, and the greater part of North America. The following remarks about the pressure distribution during the earlier part of the period are extracted from an article in the *Meteorological Magazine* for September, 1924, p. 179:—"The chart of pressure deviations for March was highly abnormal, pressure being more than 15 mb. below normal over the Azores (see p. 80 of the *Meteorological Magazine* for May, 1924). . . . This centre of negative pressure deviation A . . . moved north-eastward, and in April lay over Scandinavia. Meanwhile a new negative centre B had appeared north-west of the Azores. In May, centre A had moved into the Arctic Ocean somewhere east of Vardo, while the new centre B had moved to the neighbourhood of the west coast of Ireland. In June, centre B had in turn moved to Scandinavia and a third centre C had appeared in the North Atlantic, somewhere east of Newfoundland and south

[1] *London, Q.J.R. Meteor. Soc.*, **48**, 1922, p. 152.

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of Greenland. In July, centre B lay over the Arctic Ocean and C occupied a position between Ireland and Iceland. . . . In March, pressure was well above normal over Iceland, Jan Mayen and Spitsbergen, and this high pressure persisted throughout April, May and June." At the same time, pressure was generally above normal over a belt extending in a west-south-westerly direction from southern Russia across Italy and Spain towards Madeira. Thus the chart of deviations of pressure from normal during April to June shows a trough of pressure deficit extending from the North Atlantic across the British Isles and Scandinavia, between areas to the north and south in which pressure was above normal.

In July the type of distribution of pressure deviation showed a decided change. Pressure fell in the north, and in each month from July to October it was below normal, not only over the British Isles, but also over the Faroes, Iceland, Jan Mayen and Spitsbergen, the deficit exceeding 5 mb. in the Faroes or Iceland throughout. A chart showing the mean deviation of pressure during these four months therefore would show an area with pressure more than 5 mb. below normal extending from central Scotland to central Iceland, the deficit being greatest (6.4 mb.) at Thorshavn.

On the mean for the whole period of April to October, 1924, the greatest deficit of pressure occurs over Scotland, and the distribution of rainfall, as we should expect, was of the cyclonic type.

December, 1919 to May, 1920.

The mean chart of pressure deviations for this period shows a large area with pressure below normal, including Canada and the Eastern United States, Greenland, Iceland, the British Isles, Scandinavia, Spitsbergen and the northern coast of Asia. The deficit exceeded 5 mb. from the Faroes and Iceland to Spitsbergen. Pressure was above normal over most of the United States, and also in a belt from the Azores to China. This distribution has the effect of intensifying the normal westerly and south-westerly winds over these islands, and the rainfall distribution, as we should expect, was orographical. Pressure charts for the individual months of this period are not yet available.

July to September, 1918.

The distribution of mean pressure deviations during this period was peculiar. Pressure was above normal over practically the whole of North America, Greenland, Iceland and Spitsbergen, and below normal over almost the whole of Europe, but the deviations nowhere reached 5 mb. This distribution is practically dominated by the month of September, in which the deficit exceeded 10 mb. over a triangular area extending from Ireland to Leningrad and North Cape. During this month numerous depressions crossed the British Isles from south-west to north-east, and were especially active over the North Sea, giving very heavy rainfall. The distribution, as would be expected, was cyclonic.

November, 1914 to February, 1915.

The chart of mean pressure deviation for the whole period shows a well-marked centre of deficit over Ireland. In November,

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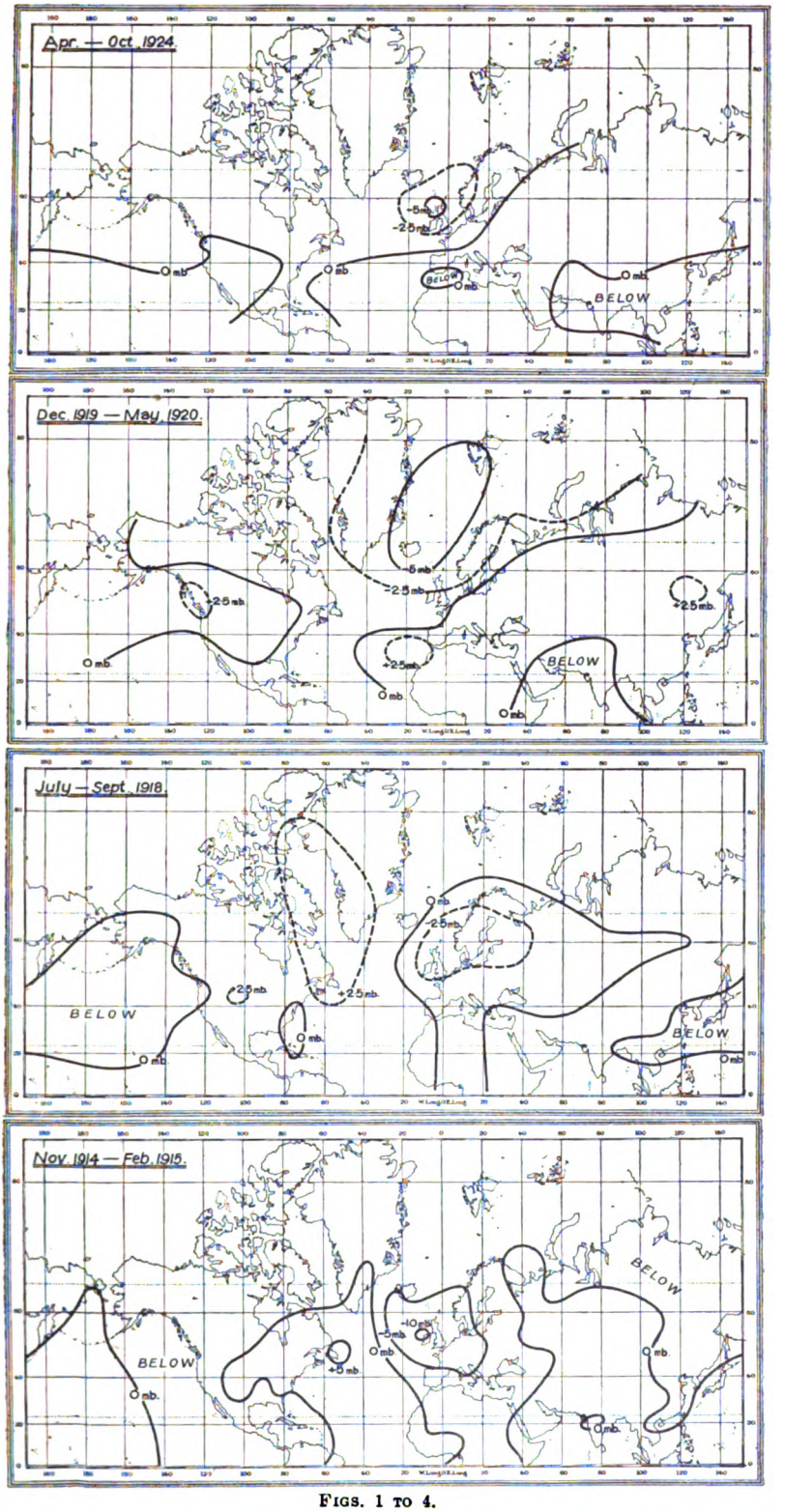

FIGS. 1 TO 4.

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pressure was somewhat below normal over the whole of Europe, Greenland and the Arctic, the deficit exceeding 5 mb. in several widely-scattered areas. The charts for December 1914, January and February 1915 resembled each other closely, all showing a deficit of 10 mb. or more centred over the British Isles or western Europe. The rainfall distribution was cyclonic in all months.

MARCH TO MAY, 1913.

The distribution of pressure deviations (deficit over Iceland, excess over the Azores) corresponds with an intensification of the normal westerly winds, and the rainfall was mainly orographical. The pressure distribution during March and April was similar to that shown in Fig. 5 (in March the deficit over Iceland exceeded 15 mb.) but in May the greatest deficit occurred over Ireland.

JUNE TO AUGUST, 1912.

The chart shows a narrow belt in which pressure was below normal, extending from Newfoundland to north Germany, with its axis in about 50° N. The greatest deficit occurred at Valencia in June, in central France in July and at London in August, so that there was a tendency for depressions to follow tracks unusually far south, giving a rainfall distribution of the cyclonic type.

NOVEMBER, 1911 TO MARCH, 1912.

Pressure was more than 5 mb. below normal over all the North Atlantic between Iceland and 40° N., the deficit exceeding 10 mb. in western Ireland. The distribution was fairly similar in all months; in February the deficit exceeded 15 mb. from the Azores to Valencia, but owing to the abnormal frequency of easterly winds, this month had a rainfall only 7 per cent. above normal. The general rainfall type was cyclonic, but south-easterly winds predominated throughout and the rainfall of north-west Scotland was below normal.

APRIL TO JUNE, 1907.

Pressure was more than 5 mb. below normal over Ireland and Scotland. This distribution suggests that the rainfall distribution should have been of the cyclonic type, but on the mean for the three months it is classed as orographical. The charts for the individual months show that in both April and June the greatest deficit of pressure occurred in the north, giving increased westerly winds and orographical rainfall. The chart of mean pressure deviations, however, is dominated by the map for May, in which pressure was much above normal over Iceland and Greenland and much below normal in the south of the British Isles, giving easterly winds and light rain in Scotland and heavy cyclonic rain in England.

JANUARY TO MARCH, 1903.

For the purpose of comparison with 1924, the long wet period in 1903 has been separated into two parts, January to March and April to October. All three months January to March showed an intensification of the Icelandic low, which was very marked in

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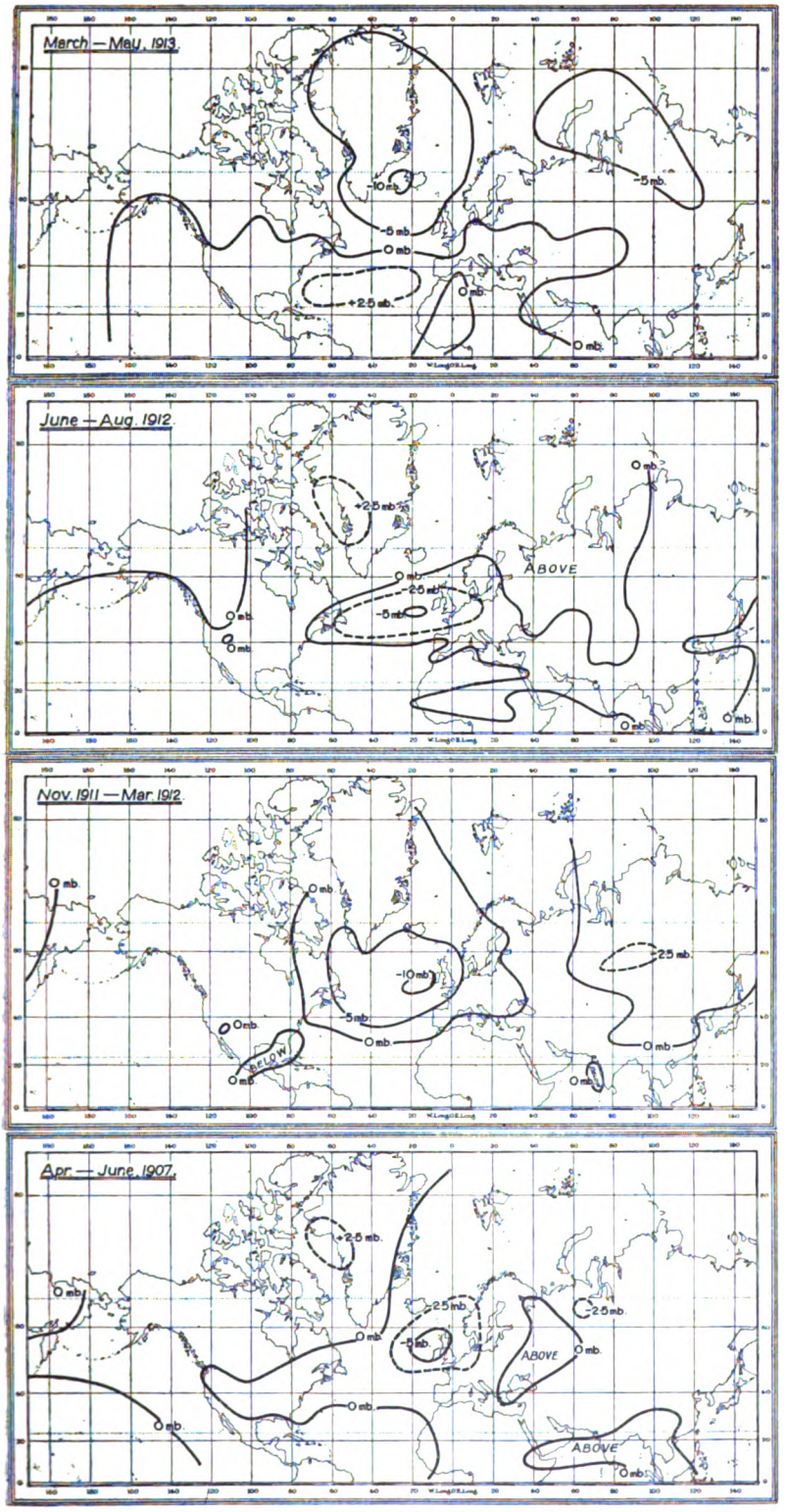

FIGS. 5 TO 8.

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February (Angmagsalik in S.E. Greenland −15.5 mb.) and March (Berufiord −18.0 mb.). The rainfall distribution was markedly orographical.

April to October, 1903.

The mean chart shows only a small area over Ireland in which pressure was more than 2.5 mb. below normal, but the charts for the individual months are highly diverse. The positions of the centres of deficit were as follows:—April, Scandinavia; May, South Greenland; June, none; July, south of Ireland; August, Faroes; September, south of Ireland; October, British Isles. The distribution in October was very intense, the deviations ranging from −13 mb. at Valencia to +9 mb. at Angmagsalik, and this month dominates the average pressure chart. The resultant of the rainfall distributions in all the separate months is rather of the cyclonic type.

August to December, 1891.

The deficit of pressure was greatest over Iceland and the Faroes, and the distribution of rainfall was mainly of the orographical type. Each month showed a deficit of pressure exceeding 5 mb., centred as follows:—September, Iceland; October, Iceland (−10 mb.); November, Portugal; December, Iceland. In November the rainfall was slightly below normal; in each of the other months it was considerably in excess.

September, 1882 to February, 1883.

The chart of the mean deviations of pressure for this period shows a large indefinite area in which pressure was below normal, the deficit exceeding 2.5 mb. from South Greenland to northern France, but nowhere reaching 5 mb. The individual months all show much the same distribution, though the actual centre of deficit varied somewhat both in position and in intensity:—September, northern France (−5 mb.); October, south-west Greenland (−5 mb.); November, Denmark (−10 mb.); December, Belgium (−10 mb.); January, South Greenland (−10 mb.); February, East Greenland (−15 mb.). The distribution of the rainfall shows corresponding variations, but the general resultant is of the cyclonic type.

April to September, 1879.

Pressure was below normal over the greater part of the northern hemisphere, the only exception being a broken belt extending part way round the globe in about 40° N. The greatest deficit occurred over the British Isles, but failed to reach 5 mb. In April, and again in June, July and August, the greatest deficit occurred over the British Isles and western Europe, and reached at least 5 mb. in each month, while in June the deficit over Ireland exceeded 10 mb. In May, pressure was generally above normal over the North Atlantic, the excess extending over the British Isles, but there was a small deficit over Iceland. In September a belt of pressure deficit extended from the Arctic across the British Isles, the

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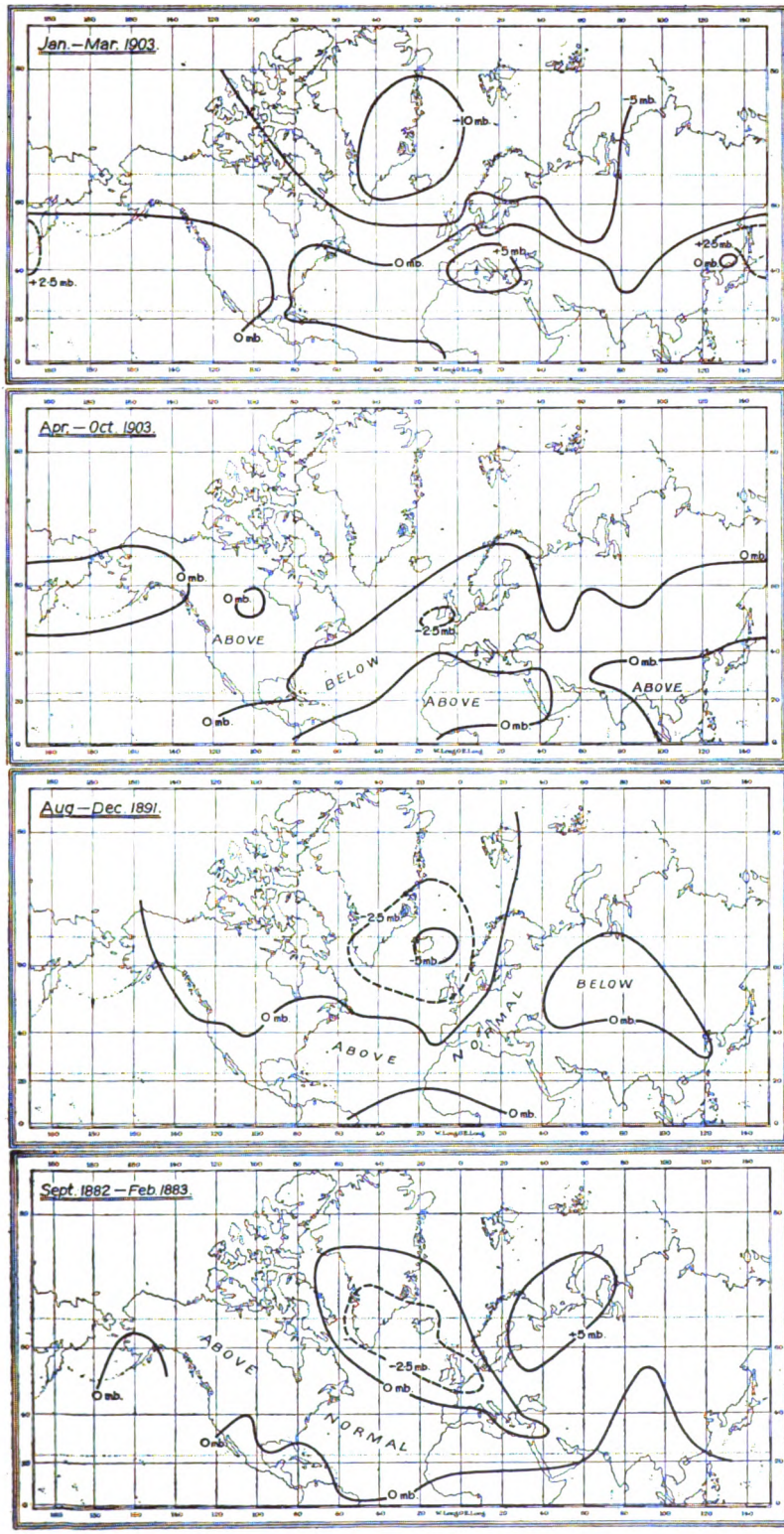

Figs. 9 to 12.

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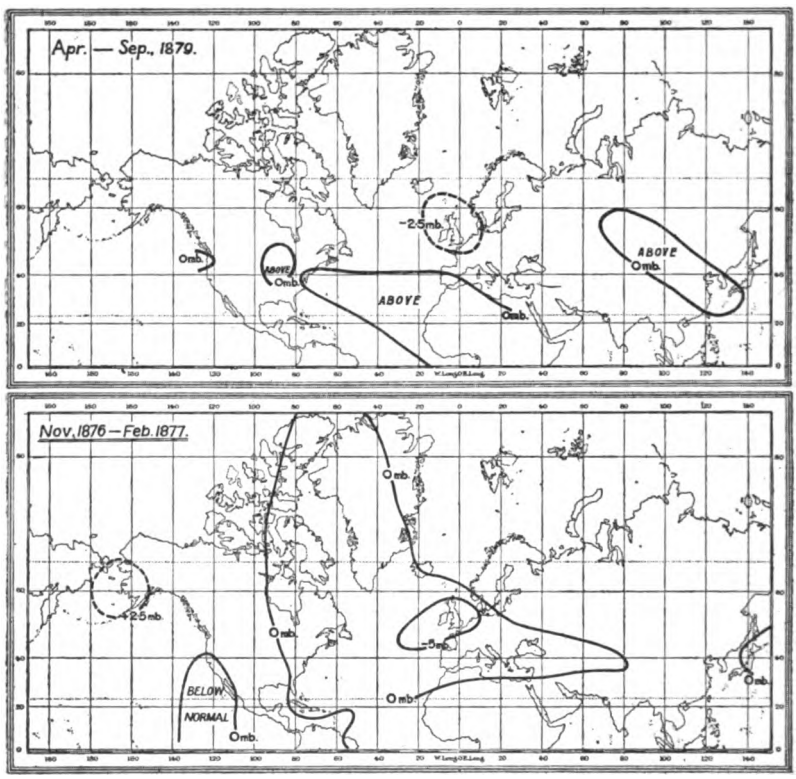
deviation being −10 mb. over eastern Greenland and exceeding −5 mb. over the Faroes and the whole of Iceland. The rainfall of the whole period was mainly of the cyclonic type.

November, 1876 to February, 1877.

The chart of the mean deviations shows a deficit of pressure of more than 5 mb. covering the British Isles. The centres in the individual months were:—November, Azores (−10 mb.); Decem-



FIGS. 13 AND 14.

ber, southern Ireland and England (−15 mb.); January, Baffin Bay to Ireland (−10 mb.); February, Scandinavia to Scotland (−5 mb.). The greatest deficit of pressure lay unusually far south, and the rainfall distribution was mainly of the easterly or non-orographical type.

Owing to lack of pressure data it is not practicable to draw maps of the mean deviation of pressure over the northern hemisphere for the earlier wet seasons enumerated by Dr. Glasspoole. Summing up the results of the study of the pressure charts shown in Figs. 1 to 14, we find that they fall into two clearly-defined types:

Type *a* includes periods in which a centre of pressure deficit lies over or near Iceland, giving an intensification of the normal

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westerly or south-westerly winds over these islands. Pressure is usually above normal over the Azores or southern Europe.

Type *b* includes periods in which the centre of pressure deficit lies over some part of the British Isles. During these periods depressions follow more southerly tracks than usual, and frequently cross these islands.

The distribution of the various wet periods among these two types is as follows :—

Type *a*.	Type *b*.
December, 1919 to May, 1920.	April to October, 1924.
	July to September, 1918.
March to May, 1913.	November, 1914 to February, 1915.
	June to August, 1912.
	November, 1911 to March, 1912.
	April to June, 1907.
January to March, 1903.	April to October, 1903.
August to December, 1891.	April to September, 1879.
	November, 1876 to February, 1877.

The pressure chart for September, 1882 to February, 1883 is intermediate between types *a* and *b*.

In discussing the drought of 1921 it was found that there were two main types of pressure distribution which were responsible for droughts. These were defined as follows :—

"Type A . . . shows high pressure to the north of the British Isles. The Icelandic minimum is shifted towards west Greenland, and the Azores maximum is feebly developed."

"Type B . . . shows a maximum pressure anomaly centred directly over the British Isles. . . . In this type . . . pressure is low over the Arctic regions."

The wet types *a* and *b* are not exactly the reverse of the dry types A and B. In type *a* the deficit of pressure lies to the north-west of the British Isles instead of to the north, and usually includes southern Greenland. In type *b* pressure is low over the British Isles, but is not necessarily above normal over the Arctic regions. It seems therefore that wet seasons are not necessarily due to a direct reversal of the conditions which lead to droughts.

One would expect type *a* to give a rainfall distribution of the orographic type, and type *b* a distribution of the cyclonic type. This is mainly true; all four instances of type *a* gave an orographical distribution, but one instance of type *b* (April to June, 1907) is also classed as giving orographical rains, and another (April to September, 1879) as giving rains of the non-orographical or easterly type. These discrepancies are due largely to the dominant part played by individual months in the mean charts for either rainfall or pressure deviation, but they are probably due partly also to minor details in the tracks followed by depressions bearing the heaviest rain; especially, in the period of "non-orographical" rain the depressions followed abnormal tracks.

Causes of Pressure Distribution favourable to Wet Seasons.

The causes which govern the pressure distribution over the neighbourhood of the British Isles are so complex that it might

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seem hopeless to disentangle them and say that it is some particular combination of a few factors which is responsible for a wet season. A few correlations in British weather have, however, been noticed which give us reason to hope that in time the mist will clear, and this collection of wet seasons affords an interesting opportunity of testing our suspicions. We should expect to find that as there are two different types of pressure distribution associated with wet seasons in the British Isles, there are at least two different sets of antecedent conditions. The wet seasons have accordingly been divided into two groups, the first group including those in which the rainfall was mainly of the orographical type, and the second group those in which it was mainly cyclonic. The factors which we have reason to believe are mainly effective in determining the seasonal distribution of pressure over the North Atlantic and western Europe are as follows :—

(*a*) The strength of the north-east trade wind nine to twelve months before.

(*b*) The strength of the south-east trade wind twelve months before.

(*c*) The strength of the north-west winds between Newfoundland and southern Greenland, which govern the strength of the Labrador current. This is indicated by the pressure difference between Sydney, Nova Scotia and Ivigtut, South Greenland, three months before the wet period.

(*d*) The amount of ice in the East Greenland current and in the neighbourhood of Iceland.

The deviation of these various factors from their normal values during or immediately preceding the wet seasons enumerated above are shown in Table I.

(*a*) North-east trade wind nine to twelve months before.

The values of the north-east trade wind shown in Table I. were obtained by means of a formula involving the mean pressure at Ponta Delgada, Gibraltar and Sierra Leone, which was deduced from the trade wind velocities for the five years 1902 to 1906.[2] The north-east trade wind affects the strength of the North Equatorial Current, and through that the strength of the Gulf Stream and ultimately the surface temperature of the North Atlantic, a relationship which was first pointed out by the late Commander Hepworth.[3] The full effect appears to take from nine to twelve months to produce. Table I. shows that in each of the four wet seasons of the orographical type for which this information is available the strength of the north-east trade wind nine to twelve months previously was below normal. In the wet seasons due to cyclonic rain this factor does not appear to have the same importance. It must also be remarked that during the period 1891 to 1915 there have been three intervals during which the velocity of the north-east trade was markedly below normal, namely, September 1895 to February 1896, April to July 1905, and October 1913

[2] "The Trade Winds of the Atlantic Ocean," Campbell Hepworth, M. W., *London, Meteorological Office, M.O.* 203, 1910.

[3] *London, Meteorological Office, M.O.* 203.

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TABLE I. DEPARTURES FROM NORMAL OF CERTAIN FACTORS DURING OR PRECEDING WET SEASONS.

WET SEASON.	Velocity of N.E. Trade 9-12 mos. before.	Velocity of S.E. Trade 12 mos. before.	Pressure Difference Sydney-Ivigtut three months before (Deviation from normal 1879-1920).	ICE CONDITIONS.		
				Greenland Sea.	Iceland.*	
				April-Aug.	Dec.-June.	During Wet Season.
	mi/hr.	mi/hr.	mb.	1000 km²		
OROGRAPHICAL TYPE.						
Dec. 1919-May 1920	−1.7	−0.3	+2.5	− 24	−31	16 (39)
March-May 1913	−0.5	−1.3	+8.9	+107	−35	12 (33)
April-June 1907	−1.2	−1.2	+6.5	+ 51	+ 4	10 (31)
Jan.-March 1903	−0.9	+(0.4)	+7.4	− 57	+ 5	0 (16)
Aug.-Dec. 1891	...	...	−0.1	+191	+14	2 (1)
MEAN	−1.2	−0.6	+4.2	+ 54	− 9	8 (24)
NON-OROGRAPHICAL TYPE.						
Nov. 1876-Feb. 1877	...	...	...	...	−39	...
CYCLONIC TYPE.						
April-Oct. 1924	+0.6	−3.2	(−?)	−188	−39	3 (36)
July-Sept. 1918	−0.6	−0.4	+4.0	+146	+31	0 (5)
Nov. 1914-Feb. 1915	−1.1	−1.2	+3.0	+ 62	(1914)+4	0 (6)
June-Aug. 1912	+0.2	+0.4	+5.6	+129	−29	30 (13)
Nov. 1911-March 1912	+0.8	+1.1	+3.7	+ 88	(1911)+66	0 (16)
April-Oct. 1903	−0.6	+2.3	+4.0	− 57	+ 5	57 (36)
Sept. 1882-Feb. 1883	...	...	−1.0	+222	+25	...
April-Oct. 1879	...	...	−1.1	− 52	−42	...
MEAN	−0.1	−0.2	+2.1	+ 32	+12	12 (20)

* Duration and Severity: one normal month=8, one severe month=16.

to January 1914, which were not followed by abnormally wet seasons.

(*b*) SOUTH-EAST TRADE.

We should expect variations in the velocity of the south-east trade wind to have an effect similar to that of variations in the velocity of the north-east trade wind, though as the waters of the South Equatorial Current have to follow a longer course than the waters of the North Equatorial Current before reaching the neighbourhood of western Europe, the interval between the variation of wind velocity and the subsequent variation of rainfall should be somewhat greater than in the case of the north-east trade. The south-east trade wind is represented by the velocity of the wind recorded by the anemometer at St. Helena. Sir Napier Shaw[4] pointed out a remarkable similarity between the annual variation of the wind velocity at St. Helena and the annual variation of rainfall in the south of England, and suspected some casual relationship. Actually, for the years in which the St. Helena wind record is complete, the correlation coefficient between the wind velocity at St. Helena and the rainfall of the British Isles in the

[4] "The Pulse of the Atmospheric Circulation," *Nature*, December 21, 1905.

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same year (using annual means) is +0.08. If we use instead the rainfall of the following year, the coefficient becomes −0.35. The variations of wind velocity at St. Helena have a close relationship to the variations of pressure and temperature, and have also shown a secular decrease since 1903. From these three relationships the missing values can be interpolated with some confidence. When this is done, the coefficients become :—Wind velocity with rainfall in the same year, −0.15; with rainfall in the following year, −0.21. These coefficients are not very hopeful, but Table I. does seem to show a slight tendency for wet seasons of the orographical type in the British Isles to be preceded by a deficiency of wind velocity at St. Helena. As with the north-east trade, the wet seasons of the cyclonic type indicate no particular relationship.

(*c*) The Strength of the NW Winds between Newfoundland and Greenland.

Since we should expect a large pressure difference between Nova Scotia and the south of Greenland to result in an abnormally large amount of cold water from the Labrador Current being driven into the North Atlantic, we should also expect it to have an effect on the rainfall of the British Isles similar to that of a weak north-east trade. This expectation seems to be borne out by Table I., from which it is seen that the five wet seasons characterised mainly by rainfall of the orographical type were all preceded by an abnormally large pressure difference between Sydney and Ivigtut, with the exception of 1891, which was practically normal. Wet seasons characterised by rainfall of the cyclonic type are less definite in their indications; in five instances the pressure difference showed a fairly large excess, but in the remaining two the pressure difference was slightly below its normal value. Data for Greenland are not yet available for 1924, but an inspection of the charts suggests that during the period January to July 1924 the pressure difference was also below normal.

(*d*) The amount of ice in the East Greenland Current or off Iceland.

Various attempts have been made to demonstrate a relationship between the ice-covered area in the East Greenland Current, or the duration and severity of the ice off Iceland, and the contemporaneous and subsequent weather in the North Atlantic and western Europe. The data for the Greenland Sea are provided by the Danish Meteorological Institute,[5] and include the area between the meridian of Cape Farewell, the east coast of Greenland, 80° N., the west coast of Spitsbergen and the meridian of South Cape. These figures refer only to the months of April to August, during which ships are in the neighbourhood; the material available for the winter months is not sufficient for a discussion. The Greenland Sea material has been discussed in detail by W. Wiese in a number

[5] "The state of the Ice in the Arctic Seas." Summary, average limits, etc. *Kjöbenhavn*, 1917.

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of recent papers.[6] The conclusions which are of most interest in this connection refer to the mean pressure distribution and the tracks of depressions. Wiese gives charts showing the mean pressure distribution in spring, summer and autumn, in years of much ice and of little ice in the Greenland Sea. In spring the Icelandic minimum is deeper in years of little ice than in years of much ice, the difference exceeding 5 mb. In summer there is very little difference between the two charts, though pressure is slightly lower over the greater part of the North Atlantic in the "heavy" years. The greatest dissimilarity is shown by the two charts for autumn, the "light" ice years showing a well-marked anticyclone over France and Germany which is absent in the "heavy" years; at the same time the Icelandic minimum is deeper, so that the pressure gradient across these islands is much steeper in "light" years. There is a tendency for depressions to follow more southerly tracks in years of much ice, especially in summer and autumn. Hence we should expect wet seasons in the British Isles to occur most frequently in years of much ice in the East Greenland Sea, and Table I. shows that this variable exceeded its normal value in eight out of thirteen instances.

The ice conditions in the northern part of the North Atlantic may also be represented by a figure denoting the duration and severity of the ice off Iceland. Such a series of values was compiled by Meinardus,[7] and the numbers for later years have been added in the Meteorological Office. Severe ice-years at Iceland are not necessarily the same as years of much ice in the Greenland Sea; rather there is a tendency for the maxima at Iceland to come a year later than the Greenland Sea maxima. This is easily understood, since the Greenland Sea figures refer to the months of April to August and to an area a large part of which is north of Iceland, while the ice-season at Iceland is mainly from March to May. That is, part of the ice which lies between Spitsbergen and Greenland in summer reaches Iceland in the following spring. In spite of this difference of dates, the pressure distribution shows the same difference between years of ice maximum and ice minimum at Iceland as between years of ice maximum and minimum in the Greenland Sea. From 1871 to 1920 the seven worst ice years at Iceland were 1874, 1881, 1882, 1888, 1892, 1911, 1915; while the seven years with least ice were 1875, 1880, 1884, 1889, 1890, 1899, 1904. Taking the difference between the mean pressure in each month during the worst years and that during the best years, we obtain:

	Jan.	Feb.	Mar.	April.	May.	June.	July.
	mb.	mb.	mb.	mb.	mb.	mb.	mb.
Stykkisholm (Iceland) ...	+2.0	−0.9	+0.7	+1.9	+2.7	+2.4	−1.7
Valencia	−0.8	+0.8	−4.4	−0.9	+0.2	−2.8	−1.6

[6] The following may be especially mentioned:
"Die Einwirkung des Polareises im Grönlandischen Meere auf die nordatlantische zyklonale Tätigkeit." *Ann. Hydrogr.*, **50**, 1922, p. 271.
"Polareis und atmosphärische Schwankungen." *Stockholm, Geogr. Ann.*, **6**, 1924, p. 273.
"Die Einwirkung der mittleren Lufttemperatur im Frühling in Nord-Island auf die mittlere Lufttemperatur des nachfolgenden Winters in Europa." *Meteor. Zs.*, **42**, 1925, p. 53.

[7] "Periodische Schwankungen der Estrift bei Island." *Berlin, Ann. Hydr.*, **34**, 1906, p. 154.

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	Aug.	Sept.	Oct.	Nov.	Dec.	Next year. Jan.	Next year. Feb.
	mb.	mb.	mb.	mb.	mb.	mb.	mb.
Stykkisholm (Iceland) ...	+1.1	+1.2	−1.3	+0.8	−0.4	—	—
Valencia	−3.1	−1.9	−4.8	−6.0	−4.7	−0.7	−1.2

The greatest effect on the pressure of Iceland occurs in the spring, when much ice raises the pressure; on the other hand the greatest effect on the pressure of Valencia does not occur until the autumn and winter following, and much ice lowers the pressure. From these considerations we should expect wet seasons characterised by orographical rainfall to occur mainly during periods when the Iceland ice was below normal, and especially in the spring of ice-poor years, and wet seasons characterised by cyclonic rainfall to occur mainly in the autumn and winter following ice-rich seasons. To test this, two columns are given in Table I., the first showing the deviation of the ice figure from normal during the months of December to June coinciding with or preceding the wet season, and the second showing the ice figure during the actual months of the wet season. In the latter column the figure in brackets shows the normal value during the months in question. The results show that during wet seasons of the orographical type, Iceland ice is generally deficient during the actual wet months, but not necessarily during the whole ice-season. Of the wet seasons of cyclonic type, five out of eight show an excess of ice during the preceding ice-season, and four out of six a deficit of ice during the actual wet months.

Summing up the results of this brief discussion, we may say that wet seasons in which the rainfall distribution is of the orographical type seem to be mainly dependent on the occurrence of three factors—a weak north-east trade wind nine to twelve months before, a large pressure difference between Sydney (Nova Scotia) and South Greenland three months before, and the almost complete absence of ice at Iceland during the wet season. A weak south-east trade wind twelve months before also assists. For a wet season of the cyclonic type the favourable conditions appear to be a large pressure difference between Sydney and Ivigtut, and a large amount of ice off Iceland during the preceding winter and spring. The wet season of 1924 is peculiar in that neither of these favourable conditions occurred, and it is possible that in spite of the rainfall being mainly of the cyclonic type, the excess was connected with the remarkably low velocity of the south-east trade wind in 1923, by far the lowest of which we have any record in a period of 32 years.

In order to test these supposed relationships further, the five factors—north-east trade, south-east trade, Sydney-Ivigtut pressure difference, Iceland ice during the preceding December to June, and contemporary Iceland ice—were combined into a single series of values, the various elements being given, roughly, the weights 1, ½, 2, 1, 2. The figures obtained in this way were smoothed over three months and compared graphically with the corresponding values of rainfall over the British Isles, expressed as percentages of normal. The period employed was from 1893 to 1915. The two curves show a certain amount of similarity, which could no doubt

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be improved by adjusting the weights attached to the different factors. The chief maxima on the curve of " factors " and on the rainfall curve are as follows:

" Factors."	Rainfall.
February to June 1894.	December 1893 to February 1894.
June to October 1896.	June to October 1896.
January to September 1897.	December 1896 to April 1897.
	October 1898 to May 1899.
	December 1899 to February 1900.
September 1900 to February 1901.	October to December 1900.
October 1902 to August 1903.	*January to October* 1903.
February to June 1904.	
December 1905 to March 1906.	November 1905 to February 1906.
March to June 1907.	*April to June* 1907.
June 1911 to March 1912.	*November 1911 to February* 1912.
(June to August 1912.)	*June to August* 1912.
November 1912 to June 1913.	*March to May* 1913.
May 1914 to March 1915.	*November* 1914 *to February* 1915.

The rainfall periods selected by Dr. Glasspoole as of special importance are shown in italic type. The general agreement of the maxima on the two curves is immediately apparent. On the other hand the concordance between the minima on the curve of factors and the occurrence of dry periods in the British Isles is very poor, and the correlation coefficient between the quarterly means of the " factors " and the quarterly rainfall percentages is only +0.38. Thus it seems probable that while the occurrence of wet seasons in the British Isles is due largely to weak trade winds, a large pressure difference between Sydney and Ivigtut, much ice in the preceding ice-season at Iceland and little ice at the actual wet period, the reversal of these conditions does not favour dry weather to the same degree. This difference is perhaps to be associated with the fact that the types of pressure distribution (deviation from normal) favourable to wet seasons are not precisely the opposites of the types of pressure distribution favourable to droughts. Even for wet seasons the relationships found are not yet sufficiently precise for forecasting purposes; the effects of departures from normal of the trade winds and of the Sydney-Ivigtut pressure difference on the subsequent pressure distribution over the North Atlantic and western Europe are known fairly definitely, but the complex effects associated with Arctic ice still need a great deal of research to elucidate them.

In discussing the drought of 1921 a tendency was suspected for droughts to occur from two to five years after sunspot maxima, and to a less extent one or two years after sunspot minima, but the tendency was not considered sufficiently definite to have any appreciable forecasting value. The relation of the wet seasons to the sunspot cycle was examined in the same way, but without result. It was impossible to say that wet seasons had even a slight tendency to occur in any particular relation to the maxima or minima of the sunspot curve.

I wish to acknowledge the assistance of Mr. A. T. Bench in drawing the charts and of Miss W. A. Quennell in compiling the data employed.

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DISCUSSION.

The PRESIDENT said he would like to ask Mr. Brooks whether he could tell them what the numerical relationships were, in particular the correlation coefficient, with the SE trade. St. Helena was a tricky place to deal with; it began by building up marked relations for fifteen years, and during the next fifteen years it proceeded to undo everything it had done before. In relation to the "southern oscillation," there was a certain amount of relationship with the rainfall of the British Isles. In the recently contributed paper by Mr. E. W. Bliss there was a correlation coefficient of —.40 for the Nile Flood with British rainfall of the following winter; and in a paper which will shortly appear there is a relationship of .42 between Samoa temperature of December to February and the British rainfall of three months afterwards; a certain amount of information derived from the southern hemisphere could thus be applied to this country.

Mr. L. C. W. BONACINA said that in regard to type A, in which the pressure is lowest over Iceland giving SW winds which brought heavy orographic rainfall, one wanted to work out what was exactly the relationship of the orographic rainfall to the general meteorological conditions prevailing. For instance, was it sufficient to get a damp strong wind from the ocean blowing against the hills? Or must you have a cyclonic discontinuity of some kind as well? Are discontinuities necessary in order that the orographic factor may take effect? Unless air had a tendency to rise for meteorological reasons, he did not think any amount of high ground would force it up; it would find some way of going round. He thought the problem should be solved. The pressure changes ought to be examined very carefully when type A prevailed.

He considered that every land-locality should be regarded as possessing an "orographic" coefficient modifying the amount of precipitation yielded by passing depressions. Thus the orographic influence would be practically zero in the Fens but enormous in the Lake District. There was known to be a slight orographic effect even when the wind crossed a low-lying coast.

Mr. F. J. W. WHIPPLE said that one could get a certain amount of information by looking at the *Daily Weather Report* maps for cases such as those mentioned by Mr. Bonacina. Straight isobars going across the British Isles were associated with strong orographic rainfall. As far as ordinary working charts would show, there was then a uniform stream of air from over the Atlantic which was forced up on reaching the high ground.

Dr. J. S. OWENS mentioned an experience which he had had some years ago which bore on the behaviour of wind striking an obstacle. It was during work on a chalk cliff some 100 ft. high; a gang of men were breaking it down with bars and allowing it to fall over on to the foreshore. There came such a strong wind off the sea blowing against the cliff that the chalk, instead of falling into the sea, came up again, most of it falling behind the men on the top of the cliff. It was very remarkable that very little except the big lumps could reach the foreshore. He wished also to ask Mr. Brooks if he were right in taking his meaning to be that if there were high pressure in the northern regions, that would induce an increase in the Labrador Current. For

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instance, if there were a difference of an inch of mercury, making a foot of difference of level in the surface of the water, there would be a surface gradient on the sea and presumably a resultant current. He thought appreciable current would be more likely due to the wind causing surface drift, not to the displacement of the water due to differences of the barometer from one point to another. Such displacement was, however, common experience in tidal work. If the barometer was very high, the tide was lower than normal.

Mr. C. K. M. Douglas (*written communication*):—The rainfall map for the period January-March, 1903 (in Dr. Glasspoole's paper), showed a large excess over the region round Edinburgh, which distorts the otherwise typical orographic distribution of the percentage. Most of this anomaly was due to the great rainstorms that occurred about January 9 and February 8, which taken together give 90 per cent. of the average total for the whole period January to March.

The rainstorm of January 8 to 10 occurred on the north side of a moving cyclone, and gave a total of 2.06 in. at Leith, of which 1.41 in. fell during the 24 hours ending 7 a.m. on the 10th.

The rain and snow of February 7 to 9 occurred on the north side of a well-marked polar front which spread down on the 7th, remained stationary on the 8th, and retreated north again on the 9th, crossing the Edinburgh district twice and giving a total of 2.30 in. at Leith, of which 1.60 fell during the 24 hours ending 7 a.m. on the 9th. Temperature contrasts were large throughout the period, the figures at 6 p.m. on the 8th being 55° F. at N. Shields, 41° F. at Leith, and 34° F. at Aberdeen. These contrasts occurred in an extensive general westerly circulation, with only a belt of calms and light NE winds just north of the front. Such slowly-moving fronts, nearly parallel to the general air movement, are produced quite frequently when there are anticyclones to the south and deep depressions far to the north.

Mr. C. E. P. Brooks said in reply to Sir Gilbert Walker that the correlation coefficient between the annual rainfall of the British Isles and the wind velocity at St. Helena in the preceding year was —0.35, but this was based on only 23 years, between 1893 and 1924. When the data for the missing years were interpolated by means of a formula, which appeared to be reliable, the coefficient dropped to —0.21. He had not yet got as far as dealing with the effect of outlying stations; as Sir Gilbert Walker knew, work of this kind took a long time. He had not seen Mr. Bliss's work on the Nile Flood when the paper was written. He thought Mr. Whipple had replied to Mr. Bonacina's remarks about orographic rainfall. His impression was that when you had straight isobars, the weather at the same place, with apparently a stable barometer, will vary considerably. At one time there may be bright sunshine and at another heavy showers. His idea with regard to orographic rainfall was that instability was usually necessary to produce rain at all. With regard to the division of the country into districts, there was a useful paper by the late Mr. Salter and Dr. Glasspoole in the *Quarterly Journal* for 1923 on "The fluctuations of annual rainfall in the British Isles considered cartographically" which covered his aspect of the question.

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A Sand Storm in the Red Sea.

Mr. G. WATTS, third officer of the *M.S. Atholprince*, sends the following particulars of a sandstorm observed in the Red Sea during a passage from Abadon, in the Persian Gulf, to the United Kingdom.

The vessel, in latitude 17° 17′ N. and longitude 40° 28′ E., was on July 11, 1926, steering on a course 331° at ten knots. The barometer read 29.43 inches and the thermometer 92°F.; ship's time 5.30 p.m. The wind since noon had been from NNW, force 1 to 2. A dark grey bank of stratocumulus then began to form to westward, where a thick haze hung over the horizon. The wind increased to force 4 to 5 from NW by N by 7.30 p.m. The atmosphere became laden with a fine, impalpable sand, very trying for the eyes and breathing, and visibility was reduced to a quarter of a mile.

These conditions continued until 9.30 p.m., when the atmosphere cleared. Visibility became very good, a ship's lights six miles distant being seen, but the wind suddenly became hot, the thermometer rising to 94°F., the barometer then reading 29.44in. At 11.15 p.m. the wind cooled, the temperature falling to 92°F., while the wind, of force 3, had backed to W by N.

This was evidently, as Mr. Watts remarks, a sandstorm from the Nubian or Bayuda desert, which are sometimes experienced by vessels in this part of the Red Sea.

Forecasting Spring Weather from Phenological Data.

Mr. I. D. MARGARY writes:—

In my discussion of the Marsham Phenological Record I ventured to give some forecasts of spring weather based on the observations of seven selected plants during January-May, and it may be of interest to record the results for 1926. The full data will appear in the Phenological Report for 1926, but the following are the chief points of interest concerning the forecast results.

The mean date of the seven plants for 1926 is:—Forecast 89 (Mar. 30), observed 79 (Mar. 20). The bloxamed value for 1924 (based on dates for 1922-1926) is:—Forecast 97 (Apr. 7), observed 95 (Apr. 5). The average date is 95 (Apr. 5).

The actual mean date for 1926 (79) is, of course, very early, though later by two days than in 1921, and surpassed in a number of previous years. The forecast only suggested that it would be "rather mild and early," somewhat of an under-statement as it proves. The bloxamed curve (as explained in the paper) is still approaching its next minimum (latest year) and although the new value for 1924 (third year since the maximum) equals that for 1923, it can be seen from the curve that the fourth year after the maximum has had a later value than the third year in the last five cycles (since 1873) and has only been earlier on two occasions in the Marsham Series. This renders it very probable that the bloxamed value for 1925 will be at least 96 (a day later) or possibly even later. Such a value necessitates a very late *actual* date for 1927; 108 to produce 96, or 113 to produce 97. Either of these actual dates would represent very late, cold springs, and the above considerations seem clearly to point to the spring of 1927 being cold and late, probably to a considerable or even very marked degree.

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REPORT ON WINTER THUNDERSTORMS IN THE BRITISH ISLANDS FROM JANUARY 1ST TO MARCH 31ST, 1925.

By S. MORRIS BOWER, F.R.Met.Soc.

[Received April 4. Read June 16, 1926.]

The annual record of winter thunderstorms which had been made for a number of seasons by Mr. C. J. P. Cave, M.A., was continued by me during the first three months of 1925. Letters were sent to about forty newspapers in London and the provinces asking for reports of any thunder or lightning which might be observed between January 1st and March 31st, 1925, both dates included. Reminders were sent at intervals during the period so that all storms should, as far as possible, have a fairly equal chance of being reported. The Director of the Meteorological Office was again good enough to circularise the observers of the British Rainfall Organisation, and the British Broadcasting Company kindly asked their listeners for thunderstorm information on several occasions. Circular letters were sent to those observers who had reported storms to Mr. Cave during the previous winter.

Nearly sixteen hundred reports were received from 823 individual observers in the British Islands, 755 of whom were in England and Wales, 44 in Scotland and 24 in Ireland. Thunder or lightning was observed somewhere in the British Isles on 57 days out of the 90, which is nine days more than in the previous winter. The number of days in each month for which reports were received from each country is shown in Table I., to which Mr. Cave has kindly permitted me to add, for comparison, the results of his investigation during the same periods in 1923 and 1924. In compiling this table, storms in progress at midnight have been recorded only for the day on which they commenced, and a few reports of flashes of light, which might have been due to electric trams or trains, and some doubtful peals of thunder have been omitted.

TABLE I.—NUMBER OF DAYS ON WHICH THUNDER OR LIGHTNING OR BOTH THUNDER AND LIGHTNING WERE REPORTED.

1925.	England and Wales.	Scotland.	Ireland.	British Islands.
January	10	12	10	17
February	20	10	8	23
March	16	5	4	17
Total for Three Months { 1925 ...	46	27	22	57
1924 ...	35	22	11	48
1923 ...	43	20	17	52

The number of days for Scotland and Ireland is very probably too low on account of the comparatively small number of observers in those countries.

The dates on which thunder or lightning was observed in each country, together with the number of reports relating to each day

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are indicated in Table II. The figures give some idea of the relative sizes of the districts affected by the storms.

TABLE II.—DAYS ON WHICH STORMS WERE REPORTED AND NUMBER OF REPORTS RECEIVED.

1925. Date.	JANUARY. Eng.	Wales.	Scot.	Ire.	FEBRUARY. Eng.	Wales.	Scot.	Ire.	MARCH. Eng.	Wales.	Scot.	Ire.
1	20	4	23	3	2	—	—	—	201	—	—	—
2	23	1	9	7	—	—	—	—	5	—	—	1
3	4	—	12	7	—	—	1	—	—	—	—	—
4	76	21	1	1	—	—	—	—	—	—	—	—
5	2	—	2	—	—	—	—	—	—	—	—	—
6	—	—	—	—	7	1	3	—	—	—	2	—
7	—	—	—	—	3	—	—	—	1	—	4	1
8	—	—	—	—	1	—	2	—	4	1	1	1
9	—	—	—	—	—	—	9	—	4	—	2	—
10	—	—	—	—	1	—	4	—	2	—	—	—
11	—	—	—	—	4	2	—	—	1	—	—	—
12	1	1	—	5	26	8	—	14	1	—	—	—
13	—	—	5	2	12	—	—	3	—	—	—	—
14	2	—	6	4	61	2	—	1	—	—	—	—
15	—	—	2	—	12	—	1	1	—	—	—	—
16	—	—	1	—	40	3	—	1	—	—	—	—
17	—	—	—	—	2	—	—	—	—	—	—	—
18	—	—	—	—	3	—	—	—	—	—	—	—
19	—	—	—	—	5	—	—	—	1	1	—	—
20	—	—	1	—	—	—	—	—	6	—	—	—
21	—	—	—	—	—	—	—	—	9	—	—	—
22	—	—	—	—	—	—	—	—	17	—	—	—
23	20	3	—	—	8	—	1	—	—	—	—	—
24	1	1	—	—	81	2	1	2	4	—	—	—
25	—	—	—	—	48	3	1	3	68	8	1	—
26	—	—	—	—	72	2	—	3	2	1	—	1
27	—	—	—	—	34	—	1	—	—	—	—	—
28	—	—	—	—	54	—	—	—	—	—	—	—
29	—	—	5	2					—	—	—	—
30	—	—	—	—					—	—	—	—
31	9	3	1	—					1	—	—	—
"Nil" reports	94	17	15	12	71	12	14	10	98	15	19	20
Totals	252	51	83	43	547	35	38	38	425	26	29	24

Maps have been drawn showing the area or areas affected by each storm and these maps have been amalgamated to show the distribution of storms during each of the several periods into which the disturbed days group themselves. The storm areas shown on the four maps in Fig. 1 have been selected as being representative of the main features of the majority of the storm maps. The number of reports received from Scotland and Ireland was too small to permit distribution maps to be drawn for those countries, so that Figs. 1-4 must necessarily include England and Wales only.

INDIVIDUAL STORMS.—*January*.—As will be seen from Table II. the first five days of January were very disturbed in comparison with the quieter nature of the rest of the month. The map in Fig. 1a shows the areas affected by the storms of January 1st to 4th. The several large and distinct districts visited on the 4th, when a secondary depression crossed the northern counties of England during the morning, are very noticeable. On January 23rd

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there was thunder and lightning over the greater part of Sussex, in some isolated parts of the Severn valley, and in Carmarthenshire. In Scotland this month was especially stormy, particularly on the north and west coasts, some stations in the latter part reporting thunder or lightning on five and six days.

February.—In England and Wales, February was extremely stormy, as will be seen from the distribution map (Fig. 3), but in Scotland it was not so disturbed as January although four storms were reported from some stations in Argyllshire. During the first ten days there were, in England and Wales, very slight storms in a number of widely separated places, but from the 11th to the 19th there were storms affecting large areas in the southern counties

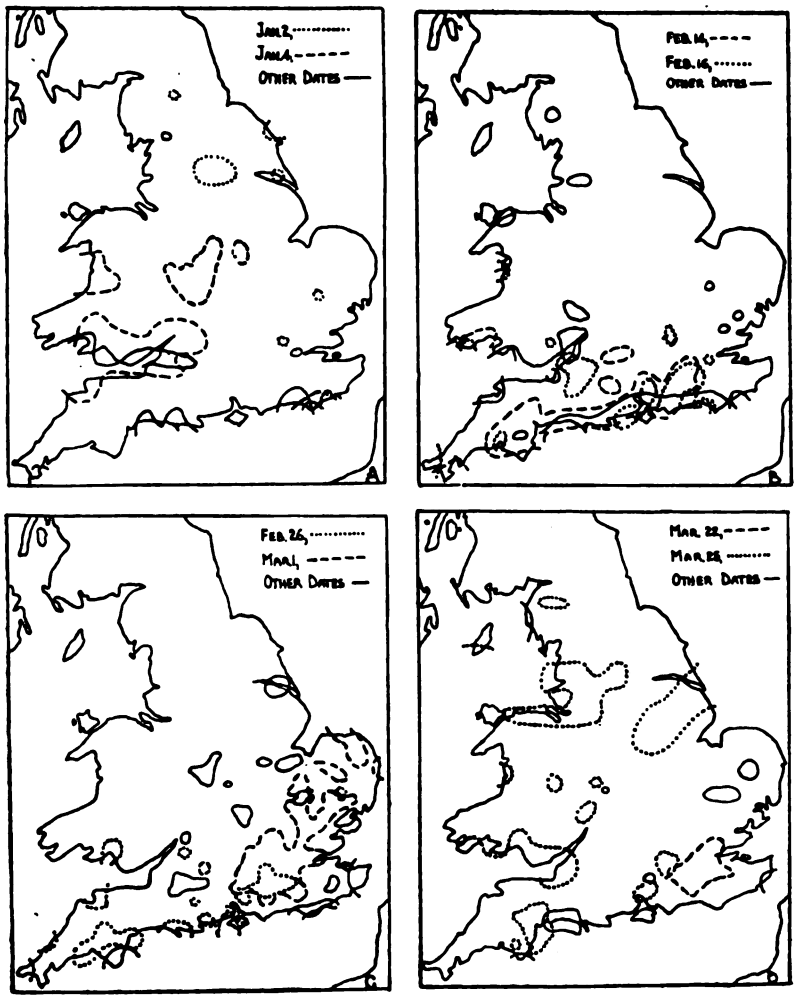

FIG. 1.—Storm areas on certain dates.

(A) Jan. 1st—4th, 1925. (B) Feb. 11th—19th, 1925.
(C) Feb. 26th—Mar. 2nd, 1925. (D) Mar. 20th—25th, 1925.

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(Fig. 1b). On the 24th thunder and lightning were reported from the valleys of both the Severn and the Thames, together with the southern parts of Cornwall, Devon and Sussex, and some of these districts were again visited on the following day when Western Somerset also had a storm. The disturbed areas of the last three days of February are shown in Fig. 1c.

March.—March 1st brought the outstanding storm of the season. It covered a very large area in the south-eastern counties of England (Fig. 1c) but was not of the usual winter type. Except for a few slight storms between the 7th and 12th the period from the 2nd to the 19th was very quiet, but on the 22nd there was a storm in Surrey and London; and on the afternoon of the 25th there were sharp thunderstorms over considerable areas in widely separated districts (Fig. 1d). The closing days of the month were again very quiet. Fig. 4 shows the distribution of storms during March.

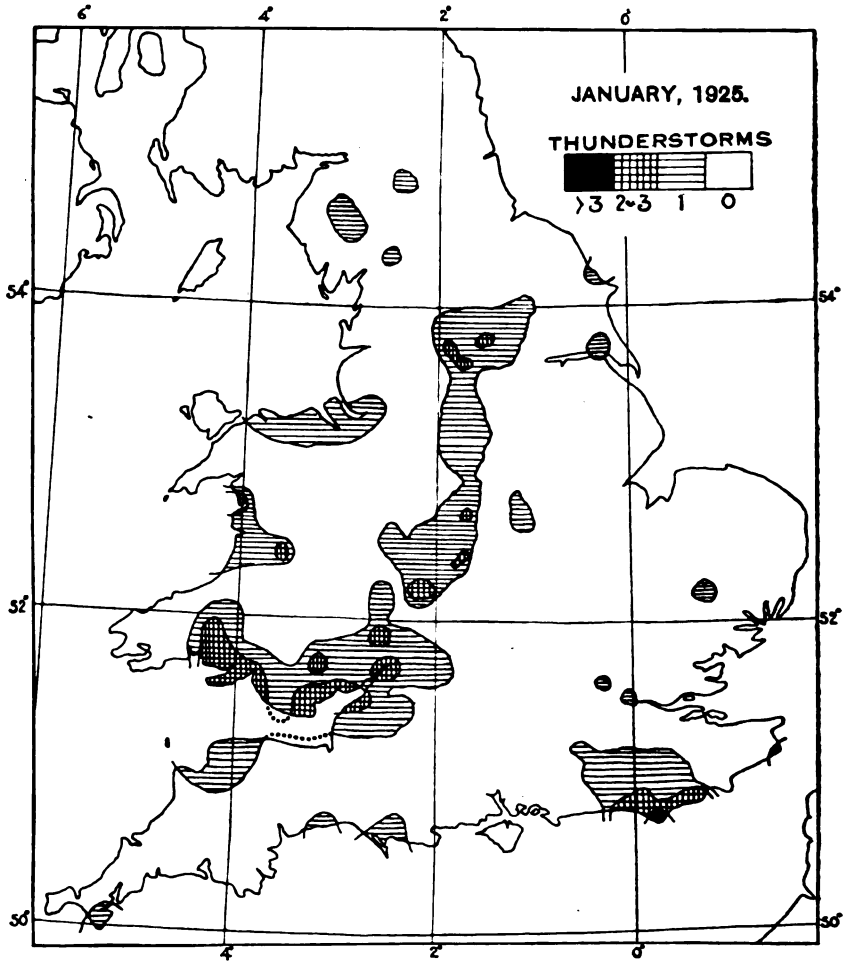

FIG. 2.—Thunderstorm distribution, January, 1925.

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The four maps in Fig. 1 have been simplified slightly in one or two places by the omission of a few very small storm areas; every reported storm is, however, shown in the large maps (Figs. 2, 3 and 4).

Distribution of Storms.—*England and Wales.*—The distribution map for the whole period, January 1st to March 31st, shows that there was a large area in Wales and also a large portion of the northern counties which were free from storms. An area of no storms runs from West Somerset through North Dorset and then northward, broadening considerably as it passes through the South-East Midland Counties, whence it runs right up to East Yorkshire; a branch lane running to Holland and the Wash. The stormiest areas are mainly on or near the south coast, the southern parts of Sussex and Surrey being especially pronounced. The large numbers of storms in the valleys of the Teign and Tamar in Devon-

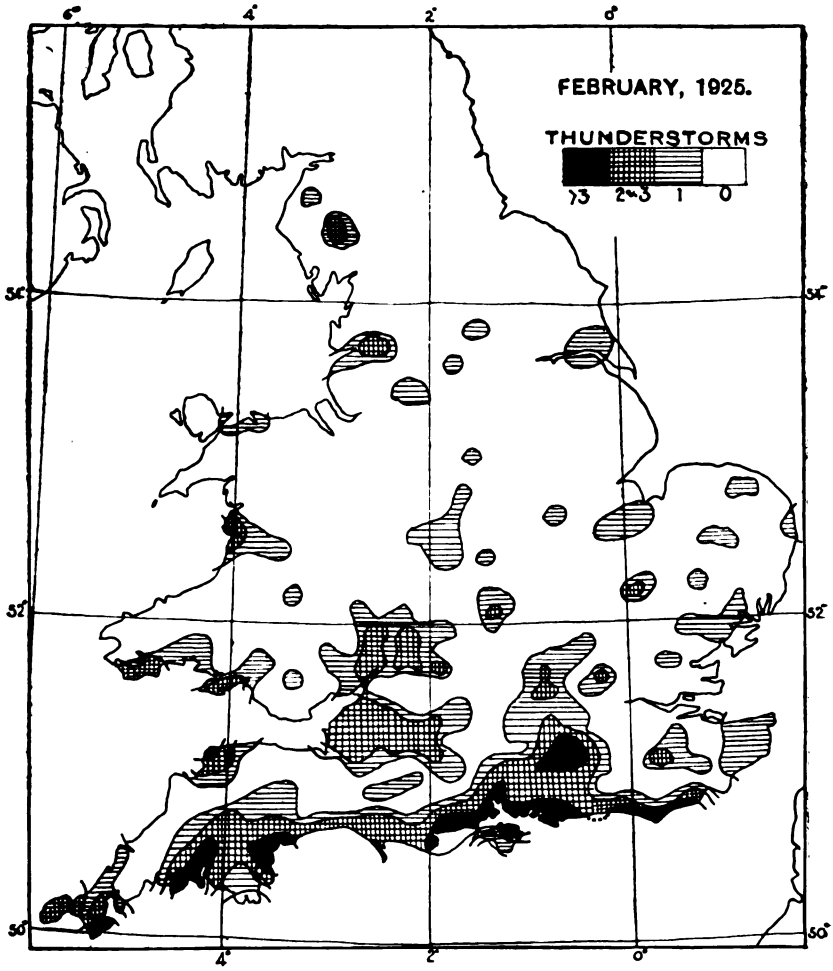

Fig. 3.—Thunderstorm distribution, February, 1925.

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shire; in the district round the Estuary of the Dovey in Central Wales; and in the lower Severn valley and round the mouth of the Bristol Channel are very noticeable. There were practically no storms in England north of a line joining Blackpool and Flamborough Head, excepting in the Lake District.

Scotland.—There was scarcely more than one storm in any of the eastern or southern counties of Scotland, but on the west coasts of Ross, Inverness and Argyll and in the Western Isles, disturbances were particularly frequent. Thunder or lightning was reported on 10 days in West Ross-shire, 8 days in Central Argyllshire and South-West Inverness-shire and on 6 days in the Isle of Skye and in parts of the southern islands of the Outer Hebrides. In most parts of the Orkney and Shetland Islands there were five storms. It is interesting to note that the majority of the Scotch storms occurred in January.

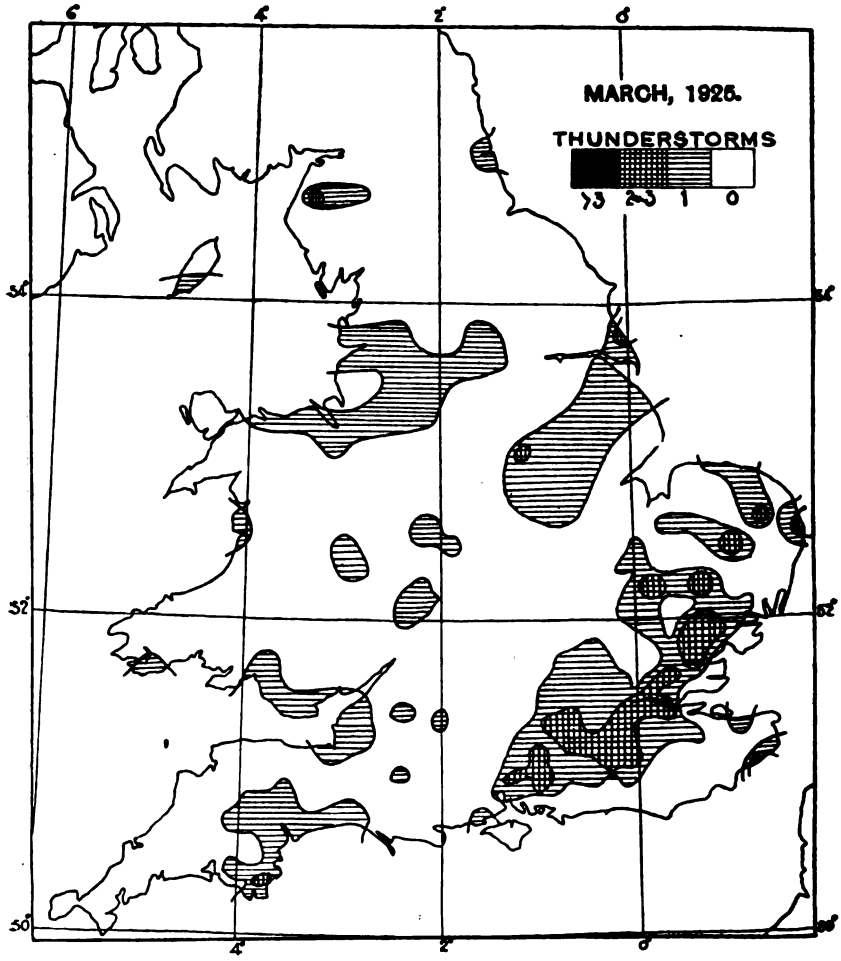

FIG. 4.—Thunderstorm distribution, March, 1925.

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Ireland.—Five storms were reported from the north-west coast of Mayo and four from the north coast of Donegal and the south-west part of Kerry. A number of places in the south of Ireland had two storms, but with the exception of the counties of Louth and Meath, the eastern and midland districts were almost undisturbed.

Channel Isles.—Thunder and lightning were reported on 7 days from Guernsey, on 3 days from Jersey and on 2 days from Alderney.

In concluding this report I should again like to thank very sincerely all those who have helped in the thunderstorm census, both by sending in reports and in other ways, and should especially like to mention the very large amount of advice and help which Mr. Cave has very kindly given me. The record is being continued during the first three months of 1926.

DISCUSSION.

Mr. C. J. P. CAVE said that the Society should be very grateful to Mr. Morris Bower for the way in which he had conducted and carried on this work, which required considerable effort. He had had to collect material from very wide areas and from a number of people, and this was not at all an easy thing to summarise. The work that he himself had done was on a smaller scale. Mr. Morris Bower had enlarged the scope of the investigation very much, and it was to be hoped that an attempt should be made to get observers in Scotland and Ireland, where they are badly needed. Mr. Morris Bower had shown no maps of Scotland and Ireland because there were not enough observers in those countries to make it possible to construct a map. It would be very valuable to have such maps because the number of storms that occurred in Scotland, especially on the west coast in the winter, is very remarkable, and it would be extremely interesting to know how far inland they extended and where they occurred. The Fellows would have noticed from the map, that Mr. Morris Bower had shown, some curious facts in distribution, namely, the crowding of the thunderstorms in the south coast and in the Bristol Channel, and on the west coast of Wales. This was a point he had noticed in former years and was one which often occurred, as also did the line of no storms from Dorsetshire to the Wash. That was a regular feature in most years during which he took observations. It was difficult at times to make out quite what constitutes a thunderstorm in a district. He had no doubt that flashes from electric trains were mistaken for lightning and it was also very difficult to differentiate between distant guns and thunder. There was an observer in Suffolk who had been an artillery officer, and he had said that he would give in no more reports of thunder because he was unable to tell the difference between thunder and the guns at Shoeburyness. He thought he was reporting too much thunder from his neighbourhood. Most of the thunderstorms that Mr. Morris Bower had reported were of the ordinary line squall type, but summer types occurred sometimes during winter. He would like to ask Mr. Morris Bower if any of the storms he had recorded this year were of the summer type.

Mr. L. C. W. BONACINA said that Mr. Morris Bower had given them a most interesting paper, but he would like to impress on him the importance of putting in the months of December and November, even

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if March had to be omitted; because, after all, if it were possible to distinguish between the winter and summer type of thunderstorm, he thought that the summer thunderstorm was one in which diurnal solar influence played a very predominant part and conversely, while winter thunderstorms were those in which diurnal solar influence played a very small part. Therefore December ought to be taken as the type month for winter storms, whereas March with its strong equinoctial sunshine would give thunderstorms, few storms would be of a purely winter type, whilst thunderstorms definitely of a summer type were not really very rare in that month. There was a marked case on March 1, 1925, included in Mr. Bower's list, of a thunderstorm of the summer type which he (Mr. Bonacina) had experienced in Windsor Great Park. Mr. Cave had discussed a severe March thunderstorm of the summer type which occurred in Hampshire on March 11, 1912. If one looked at the monthly distribution of thunderstorms in England, the outstanding maximum was in May, June, July and August, when the sunshine was strongest, and the outstanding minimum was from November to February when it was feeblest. He therefore thought that these latter four months were the appropriate ones to be included in the investigation. In regard to what Mr. Cave had said about electric flashes near towns, they certainly were abundant in winter-time, but he thought that any careful observer of Nature or trained meteorologist would, as a rule, be able to make the necessary allowance for the general conditions. With regard to geographical distribution, he supposed most of the winter thunderstorms were due to polar air that had been warmed over the sea and rendered unstable, and for that reason one would not expect them to extend very much inland. They were extremely rare in Central Europe.

Mr. D. BRUNT said there was one point which occurred to him when looking at the last slide shown on the board, and that was the very pronounced maximum frequency of thunderstorms in the Valley of the Dovey, and that to the north-east and south-east of that apparently no observations were made. He thought it would be well if we could have a map which showed exactly the number of observers belonging to each district, because if one looked at a map giving the thickness of the population, one would find that whereas the coastline near the mouth of the Dovey is relatively thickly populated, to the NE you have a considerable belt where there is no population at all, and to the south and east, Montgomeryshire, Breconshire, Radnorshire and North Pembrokeshire are thinly populated. Therefore he begged to offer the suggestion that the maps shown showed a combination of thunderstorm-cum-population. It might be that reports of thunderstorms are few from these districts because there are very few people there to observe them, whereas in a health resort like Aberdovey and its neighbourhood there would be plenty of observers with leisure to report the occurrences of thunder. The mean temperature of Aberdovey approximates to that of Bournemouth, and it is sheltered from the north and north-east more than other places on the coast. Hence its winter population is high. The southern parts of Monmouthshire and Glamorganshire, and the south-east corner of Pembrokeshire are thickly-populated industrial districts. In these districts, therefore, one has a large number of observers. He would like to know whether those districts left white on the map were really not visited by thunderstorms or whether on account of the dearth of observers the completion of the charts was impossible.

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The PRESIDENT said he would like to have for comparison charts of the frequency of summer as well as of winter thunderstorms. It was quite clear that the winter storms frequent the coasts, especially those which are warm. In America the summer storms occur very largely along the main valleys. He thought the Thames and Severn Valleys had very few of these winter thunderstorms.

Mr. R. G. K. LEMPFERT asked Mr. Morris Bower whether the material came in in such a form that he could give any information about the diurnal variation of the thunderstorms.

Mr. J. E. CLARK wished to second Mr. Bonacina's remarks about adding the months of November and December, because obviously the December thunderstorms were decidedly of the winter form. If Mr. Morris Bower had not been in communication with the Secretary of the Irish Rainfall Organization, Mr. Montagu Murphy, it might be a considerable help to him if he were.

Mr. N. W. THOMAS wished to suggest the possibility of thunderstorms having been overlooked. He lived on the borders of Shropshire and Mr. Morris Bower's appeal never reached him, so he had not made a record for last year. He was sure that in the four years he had lived there they had had many single claps of winter thunder. A single clap would come, and then, even when listening carefully, nothing further could be heard. If that happened between midnight and early morning, people would be apt to overlook it. He would like to ask the author how many observers he had. He also thought it would be a good thing in future if papers showed exactly where the observers were located. It might enable people like himself to suggest other possible observers. It might be useful also to put an appeal in provincial papers. A journalist would undoubtedly be able to help Mr. Bower.

Mr. MORRIS BOWER, in reply, said that as regards the question of observers at the mouth of the Dovey, there were a fair number in that part, and a smaller number in the surrounding district. The latter observers had sent *nil* reports, but these had only been shown on the preliminary maps. The storm of March 1 in the south-eastern counties was of a summer type, and he had had over 200 reports of it. Next winter he hoped to start on October 1 and to end on March 31. The three months done so far could then still be compared with the corresponding part of the new period. He had asked for *nil* reports last year, and at the end of Table II., in the last line but one, are shown the numbers of records reporting no storms in the various months. He had put all these records on the preliminary maps and had deduced from them the white areas on the final maps. There were one or two cases where a *nil* report had cut into an area where a storm was definitely reported, in which case it had been neglected. Where there was great divergence in one report from the others in the same area, he omitted the one report and used the others. He had not at present any statistics for hourly variation, the reported times of storms having so far only been utilised in tracking individual storms. The number of the observers was about 800 for 1925; and as regards positions, there were a large number in the south, but the rest were pretty well distributed in the northern counties. In Scotland and Ireland there were too few. For the present year he had had about 1,500 observers, the storm on February 16 in the Midlands and the south having brought a good

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increase in numbers. He had tried to get his appeal for observations to as many people as possible; he had sent to the daily papers and others in Whitaker's list, and also to the British Broadcasting Company, who had asked for observations over the wireless on four occasions.

Weather Talks by Wireless.

In the course of 1925 the Society was approached by the British Broadcasting Company as to the possibility of including meteorology in the subjects treated in their Talks and Lectures. A Committee of the Council was appointed to consider the matter, and they were able to arrange for the following talks to be broadcast on the dates mentioned:—

Sept. 22. (1) Weather and Plant Life. By I. D. Margary.
,, 29. (2) Rain. By Dr. H. R. Mill, F.R.S.E.
Oct. 6. (3) Atmospherics and the Atmosphere. By R. A. Watson Watt.
,, 13. (4) Thunderstorms. By Dr. G. C. Simpson, F.R.S.
,, 20. (5) Climate. By C. J. P. Cave.
,, 27. (6) Forecasting. By J. S. Dines.

It is gratifying to note that as a result of Mr. Margary's talk the Society has received a considerable number of inquiries from persons interested in its phenological work.

Meteorological Papers published by the Royal Society.

The following papers have been issued during the present year to those Fellows of the Society who are participating in the arrangement for the receipt of copies of the meteorological papers published in the *Proceedings* of the Royal Society:—

(1) On the formation of water waves by wind. H. Jeffreys.
(2) Measurements of the amount of ozone in the earth's atmosphere and its relation to other geophysical conditions. G. M. B. Dobson and D. N. Harrison.
(3) Atmospheric ozone and terrestrial magnetism. C. Chree.
(4) Condensation of water from the air upon hygroscopic crystals. J. S. Owens.
(5) Atmospheric diffusion shown on a distance-neighbour graph. L. F. Richardson.
(6) Discussion on the electrical state of the upper atmosphere. Opened by Sir Ernest Rutherford.
(7) On lightning. G. C. Simpson.
(8) A review of Mr. George W. Walker's magnetic survey. Sir A. Schuster.
(9) On the nature of atmospherics. Parts 2 and 3. E. V. Appleton, R A. Watson Watt and J. F. Herd.
(10) A comparison of the records from British magnetic stations underground and surface. C. Chree and R. E. Watson.

Any Fellow wishing to take part in the scheme is asked to communicate with the Assistant Secretary at 49, Cromwell Road, for particulars. Since the end of 1921, when the plan was started, 36 papers have been forwarded.

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ABNORMAL RATES OF ASCENT OF PILOT BALLOONS IN THE LOWER LEVELS OF THE ATMOSPHERE AT MELBOURNE.

By EDWARD KIDSON, O.B.E., D.Sc., F.Inst.P.

[Received April 4. Read June 16, 1926.]

I.—Ascending Currents.

Considerable emphasis has been laid recently by meteorologists on the difficulty with which ascending currents are produced on any large scale in the atmosphere by simple convection. The extreme cases presented in the accompanying table (Table I.) may, therefore, prove to be of general interest.

Since the beginning of 1922 a rangefinder has been used at Melbourne for determining the heights of pilot balloons in the early portions of their ascents. Table I. is not exhaustive but includes most of the more outstanding instances of rapid ascending currents maintained over a considerable range in altitude. A few of the examples are given only because a rapid rate of ascent was encountered at one of the other observations on the same day. In the great majority of cases the upward currents continued until the level of cumulus cloud was reached. There were, of course, many occasions when the ascending currents were only slightly smaller in magnitude than those listed.

During 1922-24 ascents were made at 09.30 h., 11.00 h. and 15.30 h. on all week days except Saturday when there was no afternoon ascent. During 1925 the 11.00 h. observation was discontinued. The balloon was observed at the instants at which it should have reached 100, 200, 300, 400, 500, 700, 900, etc., metres. The observations are numbered according to the nominal height in hundreds of metres.

The balloons used were small, mostly from 8 to 12 grams in weight. For the ascents appearing in the second to seventh places, inclusive, in Table I., the balloons were filled to rise at the rate of 100 metres in 40 seconds. For the remainder the rate of ascent was 100 metres in 45 seconds, the formula adopted being that due to J. S. Dines.

$$V = q\frac{L^{\frac{1}{2}}}{(W+L)^{\frac{1}{2}}}$$

q being taken as 84. In the mean, the height at the first reading is slightly higher than that given by the formula, and thereafter, for some considerable range at least, lower. Neither these departures from the formula nor the errors in the rangefinder readings are, however, important in comparison with the upward currents indicated in the ascents under discussion. The rangefinder is of the infantry pattern with a 75 cm. base and is accurate for distances up to about 3,000 yards if in good adjustment.

In the table, h is the height in metres at the observation of which the number appears in the first line, V the velocity of the wind in metres per second between the height h and that at the previous observation, and ϕ the direction in degrees from north round by east. Thus, in the first ascent, at the fifth observation,

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TABLE I.—Rapid Ascending Currei

Date.			Obsn. No.	1			2			3			4			5			7	
			Time.	h	V	ϕ	h	V	ϕ	h	V	ϕ	h	V	ϕ	h	V	ϕ	h	V
D.	M.	Yr.	hrs.	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.
21	Feb.,	'22	11.00	132	7.0	345	277	6.8	336	498	4.8	318	718	6.9	318	1008	7.4	321	...	...
4	Nov.,	'22	09.30	—	—	—	266	1.6	163	429	3.8	154	586	2.2	152	751	1.7	200	1085	1.0
14	Dec.,	'22	09.30	197	4.8	203	370	4.6	243	538	4.2	252	719	2.5	243	841	2.1	238	1091	2.0
8	Jan.,	'23	09.30	129	6.0	265	297	7.7	260	480	8.9	262	662	7.2	264	840	6.6	260	1095	6.1
8	Jan.,	'23	11.00	170	5.7	235	285	9.9	235	335	7.1	240	465	8.1	247	640	9.9	241	933	6.0
26	Feb.,	'23	09.30	178	5.4	137	369	5.8	124	580	5.5	120	726	6.5	143	845	7.2	149	1035	6.3
26	Feb.,	'23	11.00	101	5.9	117	287	4.2	168	465	6.6	156	632	7.4	117	...	...	...	...	...
19	Sep.,	'23	11.00	129	5.0	348	259	5.6	340	426	5.8	338	635	6.7	358	835	6.3	348	...	...
21	Sep.,	'23	11.00	158	11.7	278	415	14.8	271	701	16.2	284	930	15.2	280	1169	15.2	270	...	...
26	Oct.,	'23	11.00	—	—	—	176	10.6	332	351	11.3	325	801	10.9	323	1202	8.3	282	1580	8.8
1	Nov.,	'23	11.00	150	9.1	282	386	13.0	280	571	12.0	289	910	17.2	288	1150	17.2	293	1420	18.0
1	Nov.,	'23	15.30	161	7.5	278	341	10.9	261	559	14.1	258	738	13.2	262	948	14.3	261	1260	11.5
7	Nov.,	'23	15.30	227	7.5	234	489	9.5	227	670	11.5	233	775	8.9	235	938	9.2	244	1260	8.1
15	Nov.,	'23	15.30	168	7.1	245	434	12.6	250	—	—	—	812	15.1	248	970	14.7	247	1285	11.9
21	Nov.,	'23	09.30	—	—	—	181	6.9	167	—	—	—	518	8.0	205	712	8.5	200	1068	6.7
21	Nov.,	'23	11.00	55	8.6	190	192	7.5	197	400	8.5	206	630	9.5	198	820	6.2	203	1090	6.5
19	Dec.,	'23	09.30	185	6.8	249	356	8.7	247	512	9.7	250	692	9.7	250	856	10.4	240	1070	10.0
7	Jan.,	'24	15.30	156	10.2	248	334	11.4	250	513	8.6	252	720	9.7	255	872	10.3	255	1068	11.9
8	Jan.,	'24	11.00	39	6.0	325	144	9.4	314	309	4.5	295	461	6.1	294	725	5.8	281	1168	7.7
12	Jan.,	'24	11.00	80	6.3	262	147	6.9	256	248	6.3	250	451	5.9	241	676	3.7	250	1040	3.6
25	Jan.,	'24	15.30	180	9.5	186	445	10.6	183	669	7.7	187	810	9.4	201	918	10.4	210	1165	11.4
16	May,	'24	15.30	138	7.1	358	310	9.8	364	427	8.3	362	539	6.9	354	—	—	—	1100	11.7
4	Sep.,	'24	11.00	189	4.2	254	380	6.9	249	525	5.2	238	629	5.7	244	...	...	...	...	...
29	Sep.,	'24	15.30	226	6.4	207	406	7.8	196	618	9.9	190	775	10.2	191	892	10.7	190	1170	11.5
8	Oct.,	'24	09.30	—	—	—	184	10.2	267	284	10.0	262	481	11.7	257	723	8.1	245	...	...
8	Oct.,	'24	11.00	—	—	—	354	9.0	271	578	8.2	276	785	7.9	266	968	8.0	268	...	...
21	Oct.,	'24	15.30	223	11.1	211	415	12.6	201	590	16.0	197	768	17.1	196	880	14.2	193	...	...

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IN THE ATMOSPHERE AT MELBOURNE.

9			11			13			
h	V	φ	h	V	φ	h	V	φ	
m	m./s.	°	m.	m./s.	°	m.	m./s.	°	
...	...	...	...	...	...	...	...	...	In Cu
...	...	...	...	...	...	...	...	...	In Fr
...	...	...	...	...	...	...	...	...	,, Ci
...	...	...	...	...	...	...	...	...	In Cu ing.
1340	8.3	238	1560	6.3	251	...	...	...	,, Burst.
...	...	...	...	...	...	...	...	...	In St- ing.
...	...	...	...	...	...	...	...	...	In Cu ing.
...	...	...	...	...	...	...	...	...	,,
...	...	...	...	...	...	...	...	...	In Cu read
...	...	...	...	...	...	...	...	...	Reach later for
...	...	...	...	...	...	...	...	...	Passe then cour
1500	7.8	268	...	...	...	...	...	...	Behin neat
...	...	...	...	...	...	...	...	...	In N ing.
...	...	...	...	...	...	...	...	...	Behin betv ings
1230	6.5	191	...	...	...	...	...	...	Behin ings betv reac
1570	16.0	242	...	...	...	...	...	...	In C reac
...	...	...	...	...	...	...	...	...	In N reac
1465	11.6	277	1710	12.7	272	2020	16.0	275	In Cu
...	...	...	...	...	...	...	...	...	In C 140
1310	10.8	222	...	...	...	...	...	...	In Cu but
360	12.4	333	...	...	...	...	...	...	In clou
...	...	...	...	...	...	...	...	...	In cl last
1430	9.1	185	...	...	...	...	...	...	In cl Nb
...	...	...	...	...	...	...	...	...	In c Cu
...	...	...	...	...	...	...	...	...	In Cu
...	...	...	...	...	...	...	...	...	In Cu

Date.			Obsn. No.	1		Remarks.
			Time.	h	V	
D.	M.	Yr.	hrs.	m.	m./s	
27	Nov.,	'24	11.00	223	3.	sed through cloud) between 7th and Note change in rate of ascent. Bal rose very little be st.
27	Nov.,	'24	15.30	148	8.	ent to previous. C bably between 7th ngs. Thunder sev iously in Victoria.
10	Oct.,	'25	09.30	182	4.	id hail reported in t morning.
15	Oct.,	'25	15.30	108	8.	of range.
2	Nov.,	'25	09.30	210	2.	
18	Nov.,	'25	15.30	131	7.	previous evening, o southerly winds.
23	Dec.,	'25	09.30	192	2.	of ascent also at 1

Date.			Obsn No..	1	
			Melb. Stan. Time.	h	V
D	M.	Yr.	hrs.	m.	m./s
16	Jan.,	'22	11.00	110	7.
20	Jan.,	'22	16.00	55	7.
3	Mar.,	'22	09.30	99	6.
11	Aug.,	'22	11.00	78	6.
13	Dec.,	'22	11.00	98	8.
27	Dec.,	'22	09.30	27	12.
29	June,	'23	11.00	154	10.
22	Aug.,	'23	11.00	95	8.
17	Sep.,	'23	15.30	98	11.
29	Sep.,	'23	11.00	84	12.
19	Oct.,	'23	09.30	99	6.
19	Oct.,	'23	15.30	97	7.
9	Nov.,	'23	11.00	94	9.
13	Nov.,	'23	11.00	55	5.
3	Dec.,	'23	09.30	76	11.
2	Jan.,	'24	11.00	—	—
15	Jan.,	'24	15.30	52	8.
30	Jan.,	'24	11.00	—	—
4	Mar.,	'24	15.30	67	8.
22	Oct.,	'24	15.30	—	—
31	Oct.,	'24	09.30	84	11.
29	Nov.,	'24	11.00	72	5.
3	Dec.,	'24	15.30	83	6.
5	Feb.,	'25	15.30	119	6.

Southward.
n Polar Air.
nania.
ery low also at 11.00
gh approaching.
s. Feeble low pres-
n and trough to W.
ense cyclone develop-
to W.
tion.
ubsequently developed
hing.
h approaching.
ation.
nt from N. Cyclone
d N. of station.
tion; troughs shallow.

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TABLE I.—Rapid Ascending Currents

Date.			Obsn. No. / Time.	h	2			3			4			5			7		
D.	M.	Yr.	hrs.	m.	φ °	h m.	V m./s.	φ °	h m.	V m./s.	φ °	h m.	V m./s.	φ °	h m.	V m./s.	φ °	h m.	V m./s.	φ °
21	Feb.,	'22	11.00	13																
				4	282	458	5.1	280	725	3.7	290	963	5.1	207	1160	6.3	207	1425	7.8	203
4	Nov.,	'22	09.30	—																
14	Dec.,	'22	09.30	19																
8	Jan.,	'23	09.30	12	275	337	9.1	276	496	9.9	266	651	8.8	268	768	7.4	265	1155	11.0	275
8	Jan.,	'23	11.00	17																
26	Feb.,	'23	09.30	17																
26	Feb.,	'23	11.00	16	288	416	5.6	288	652	7.1	284	755	6.2	291	820	7.7	282	1110	7.8	281
19	Sep.,	'23	11.00	12	330	308	7.2	333	575	9.3	335	783	10.5	331	968	10.2	334	1332	11.5	327
21	Sep.,	'23	11.00	15	165	460	2.8	206	736	3.1	202	877	3.0	220	...	...	...	...	...	...
26	Oct.,	'23	11.00	—																
1	Nov.,	'23	11.00	15	186	360	6.1	197	581	6.6	193	709	5.1	181	...	...	...	...	...	...
					190	305	2.7	181	518	4.0	188	—	—	—	911	5.5	238	1050	4.8	274
1	Nov.,	'23	15.30	16																
7	Nov.,	'23	15.30	22																
15	Nov.,	'23	15.30	16																
21	Nov.,	'23	09.30	—																

TABLE II.—Low Rates of Ascent of

				2			3			4			5			7		
			φ	h	V	φ	h	V	φ	h	V	φ	h	V	φ	h	V	φ
21	Nov.,	'23	11.00	5	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	m.	m./s.	°
				1	180	234	6.6	180	308	5.1	175	314	4.3	172	320	3.5	190	371	3.5	185
				5	144	120	8.5	142	125	5.6	133	132	6.3	138	142	8.0	138	339	6.4	151
19	Dec.,	'23	09.30	18	232	141	6.8	233	166	7.4	234	205	8.2	235	240	8.2	235	272	6.7	237
				5	324	118	6.0	323	186	5.6	322	222	6.8	318	215	8.0	317	247	7.7	318
7	Jan.,	'24	15.30	15	288	104	9.0	290	125	8.5	286	177	7.8	282	221	8.0	280	251	8.4	202
				5	357	107	13.4	359	107	17.8	366	146	16.1	364	167	12.0	365	337	20.0	365
8	Jan.,	'24	11.00	3	365	225	9.0	359	262	14.1	357	255	13.7	364	255	14.0	362	361	17.0	365
12	Jan.,	'24	11.00	8	16	145	9.9	10	193	10.9	368	264	11.7	14	311	11.5	15	381	11.0	13
				1	363	44	15.5	366	14	17.3	12	125	10.6	367	198	19.2	365	...	...	...
25	Jan.,	'24	15.30	18	348	157	16.6	360	233	22.8	365	250	15.8	364	266	24.0	361	378	19.2	366
16	May,	'24	15.30	13	180	128	6.0	175	164	6.2	174	212	6.4	173	264	6.6	171	329	6.0	173
4	Sep.,	'24	11.00	18	195	157	9.5	190	162	7.5	205	174	8.4	205	168	9.5	207	338	8.8	190
				6	212	108	9.6	212	163	15.2	210	158	11.1	214	185	13.2	214	260	9.8	213
29	Sep.,	'24	15.30	22	11	73	5.4	369	73	5.6	365	72	5.8	14	76	5.8	307	180	7.0	306
				7	316	176	11.1	309	253	13.6	303	280	15.1	289	340	17.0	301	308	15.0	306
8	Oct.,	'24	09.30	—	—	90	2.4	202	156	2.1	203	190	2.1	205	240	1.9	206	347	2.0	189
				5	307	201	8.3	322	318	9.1	332	335	12.0	330	322	12.0	327	324	10.0	321
					—	88	3.7	147	88	4.0	157	123	3.3	160	161	3.6	157	219	3.9	154
8	Oct.,	'24	11.00	—	30	157	9.3	31	240	9.0	28	274	10.0	23	327	7.8	31	305	8.1	2
21	Oct.,	'24	15.30	22	—	163	3.0	248	190	2.7	236	182	2.1	231	207	1.4	225	355	3.2	235
				7	360	171	14.1	360	231	15.0	364	270	16.2	360	310	15.5	361	365	16.7	359
				1	332	—	7.2	333	168	7.0	326	238	7.2	330	280	6.6	332	380	7.5	329
				0	100	164	6.1	104	175	6.0	104	180	4.5	175	214	6.1	178	281	6.2	18
				1	146	214	3.8	133	215	3.0	132	223	3.1	103	180	4.5	127	—	4.3	141

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THE ATMOSPHERE AT MELBOURNE.—(*continued*).

9			11			13			Balloon Lost.	Remarks.
h	V	φ	h	V	φ	h	V	φ		
m.	m./s.	°	m.	m./s.	°	m.	m./s.	°		
1020	13.1	273	1630	12.0	254	...	...	...	In distance after 4 more readings with theodolite.	Balloon passed through cloud (from 285°) between 7th and readings. Note change in ve city and rate of ascent. Ball probably rose very little bef it was lost.
1475	10.2	295	1512	9.7	306	...	...	...	In distance some readings later.	Similar ascent to previous. Cl level probably between 7th a 9th readings. Thunder seve days previously in Victoria.
1285	10.5	271	...	...	...	...	...	...	In Cu one minute after last reading.	Thunder and hail reported in V toria next morning.
1575	7.9	300	...	...	...	...	...	...	In Cu three readings later.	Passed out of range.
...	...	...	...	...	...	...	...	...	In Cu soon after 3rd reading.	
...	...	...	...	...	...	...	...	...	In Cu (Nb-form) after last reading.	Thunder previous evening, w change to southerly winds.
...	...	...	...	...	...	...	...	...	Behind rapidly forming Cu. Through cloud just after 5th reading.	High rate of ascent also at 15 hrs.

PILOT BALLOONS AT MELBOURNE.

9			11			13			Remarks.
h	V	φ	h	V	φ	h	V	φ	
m.	m./s.	°	m.	m./s.	°	m.	m./s.	°	
422	3.6	177	510	4.0	174	600	5.8	175	On E. shoulder of anticyclone.
653	7.1	149	...	...	...	...	...	...	Anticyclone with long axis lying to Southward.
316	8.1	236	398	8.0	232	...	...	...	On E. shoulder of anticyclone.
432	8.5	313	585	8.9	306	675	7.4	286	In secondary low pressure trough in Polar Air.
273	9.3	290	384	7.5	290	549	9.0	285	Feeble cyclone developing over Tasmania.
...	...	...	...	...	...	...	...	...	On E. edge of deep V-depression. Very low also at 11.00 hours.
...	...	...	...	...	...	...	...	...	Intense V-depression with wide trough approaching.
360	12.1	304	...	...	...	...	...	...	Anticyclone in E. New South Wales. Feeble low pressure trough approaching.
...	...	...	...	...	...	...	...	...	Very wide and intense V-depression and trough to W. Very low also at 11.00 hours.
...	...	..	...	...	...	...	...	...	Anticyclone centre just passed. Intense cyclone developing to W.
441	6.0	178	550	6.0	180	700	7.3	177	Near centre of anticyclone.
484	11.4	198	649	8.6	189	...	...	...	
...	...	...	...	...	...	...	...	...	In rear of depression. Anticyclone to W.
389	7.5	305	729	8.0	300	1042	8.5	357	Anticyclone centre passing N. of station.
474	13.0	301	...	...	...	...	...	...	Rather irregular depression to S., subsequently developed into cyclone.
462	1.0	151	523	1.1	230	603	0.9	103	Low gradients; anticyclone approaching.
371	11.8	324	487	9.0	324	...	...	...	Wide, shallow, but deepening trough approaching.
249	3.4	152	282	4.0	153	459	4.7	155	Anticyclone centre passing S. of station.
449	10.0	25	600	10.0	30	...	...	...	On E. edge of strong upper current from N. Cyclone developed to W.
400	3.2	248	483	3.5	252	551	2.7	253	Anticyclone centre very near; passed N. of station.
...	...	...	...	...	...	...	...	...	Near trough of depression.
476	9.2	320	515	12.4	327	...	...	...	On rear shoulder of anticyclone.
372	5.2	176	572	7.1	178	741	5.8	179	Near centre of anticyclone.
350	2.7	118	589	4.5	107	802	2.2	122	Anticyclone centre passing S. of station; troughs shallow.

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where the height should have been 500 metres, it was observed to be 1,008 metres; the mean wind between that height and 718 metres, at which the previous observation was taken, was 7.4 metres per second from 321°.

Australian weather consists of the passage eastwards of a series of anticyclones with intervening low pressure troughs, which latter terminate southwards in cyclones or V-depressions. On the forward side of the depression is the stream of "equatorial air," blowing from some northerly direction, while in its rear and as far as the axis of the oncoming anticyclone is the "polar air," in which the winds have, in general, a southerly component.

The following are the most salient features of Table I.:—

1. Almost all the ascents are in the "polar air," which, coming from higher and colder latitudes, is receiving heat rapidly from the earth's surface, especially while over the land.
2. With one exception, the ascents all occur in the months September to February inclusive, that is, in the months when the land is warmer than the air and, what is more important, than the sea. The distribution of the cases in which a height of more than 1,000 metres was measured at the No. 7 reading during three years is as follows:—

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Decr.
11	9	0	1	2	0	1	3	8	9	14	9

As would have been expected, the rapid ascending currents are encountered with the greatest relative frequency at 11.00 hours and the least at 09.30 hours.

3. In all but four cases the wind is moderate or strong. Thus the convection is not produced in stagnant air lying over some especially warm portion of the ground surface but in winds of which the mean velocity is considerably above the average.

In the first ascent the wind is northerly but the westerly change ("polar front") arrived at the surface during the ascent and a thunderstorm followed. This, then, was not a case of simple convection.

On September 19, 1923, the balloon was in the main northerly current and the causes of the rapid ascent are not so obvious, the varying moisture content of the air probably being involved, as well as insolation and radiation.

On October 26, 1923, occurred the most remarkable upward currents so far recorded. At one stage they were such that no rain drops could fall through them. On this occasion cumulus cloud developed rapidly until the whole sky was covered by it. At the time, Melbourne appeared just to be coming under the influence of a low pressure trough, the axis of which was inclined very much to the west of north. The northerly winds had not been long established, however, and a change to southerlies followed some time after the ascent. It appears probable that a wedge of warm northerly air was being raised *en masse* as a subsidiary cold front converged on the preceding main one. Possibly the whole of the air was of "polar" origin.

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The exceptional ascent of May 16, 1924, the only one of those listed which does not occur in a spring or summer month, was also in a northerly wind. A cyclone had developed previously off the coast of New South Wales and had become very intense as it moved across the Tasman Sea. The eastern portions of the Australian continent were flooded with the cold air in the rear of this cyclone. It is suggested that the balloon rose in a portion of this air which was returning as a northerly current owing to the advance of the new low pressure trough but was still being heated by the land surface.

In all the other cases in which a northerly current is shown, it is either a local effect or due to a temporary backing of the wind with the approach of a secondary front in the polar air. Possibly the heating of the air indicated by the upward currents is the cause of the development of the secondary front.

Not only did most of these ascending currents occur in rapidly moving air, but in most instances the cirrus cloud also was moving rapidly from some direction south of west. Many of the ascents occurred in weather of a westerly type in which the isobars tend to be parallel to the southern fringe of the continent, when strong westerly winds blow and pressure systems move rapidly. It is, therefore, probable that the air had usually been moving rapidly for long distances and had a far southern origin.

It will be seen that the balloon was, in nearly every case, lost in cumuliform cloud. On a considerable proportion of the occasions, also, hail or thunder was associated with the air movement in which the rapid upward current was observed. Rain usually occurred in the same air body.

The facts that the winds were strong, that rapid rates of ascent tended to be observed more than once during the same day and that hail and thunder were frequently reported, seem to indicate that strong convection currents are very general in these streams of polar air and that they are an important factor in atmospheric processes.

In some cases the wind reaches a maximum near the top of the ascending current and shows a distinct decrease in velocity at greater heights. The velocity may, therefore, be derived partly from the heat energy supplied.

For a large proportion of the ascents observations of the surface temperature and humidity a few minutes before the commencement are available. If the height at which condensation would be expected to take place in a mass of rising air be computed from these data it is found, usually, to agree closely with the observed height at which the balloon entered cumulus cloud. Sometimes, of course, the cloud will be higher than the computed height. On one occasion, also, it was lower, but at this time there was a considerable change in wind direction as the altitude increased.

II.—Descending Currents.

Descending currents are a much more difficult problem than ascending. It is not easy to account for rapid downward currents, the counterpart of the ascending current being generally believed to be subsidence over a considerable area. Furthermore, if a

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descending current is confined to a particular layer and persists therein, a pilot balloon may be kept in that layer for a more or less protracted period. Thus, at Melbourne, the balloon may have passed out of range for the rangefinder before rising through the layer. The significance of the observation becomes, therefore, difficult to determine.

Balloons frequently ascend at less than the normal rate at Melbourne and typical cases of marked departures are given in Table II. in which the various quantities have the same significance as in Table I. The nominal rate of ascent was 100 metres in 40 seconds for the first, fourth, fifth and sixth ascents, and 100 metres in 45 seconds for the remainder.

Ascents during the years 1922-25 in which the height at reading No. 7 was less than 400 metres occurred at the rate of about 1 in 40 and were distributed throughout the year as follows:—

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
10	8	5	2	0	1	2	5	6	9	11	9

The number in December is relatively small, probably owing to the number of holidays in this month and the consequent small total number of ascents. The annual distribution is similar to that of the mean rate of ascent, that is, the greater the mean rate of ascent, the greater the chances of a very low one. Other quantities having a similar annual variation are the degree of turbulence of the atmosphere and the mean velocity of surface winds. Again, very low rates of ascent were most frequent at 11.00 hours and least at 09.30 hours. The greater the wind velocity, also, the greater their relative frequency. Instances occur in practically all types of weather. There is a special tendency for the balloon to keep low when the station is near the centre of an anticyclone, but the results of this effect are usually much smaller than those now being considered.

The foregoing suggests very strongly that the low rates of ascent are, to a large extent at least, the product of turbulence, the balloon being caught in the descending portions of eddy currents.

If the air be turbulent it is clear that the balloon will ascend at rates sometimes above and sometimes below the normal. It did not seem to the writer, however, that such large departures could be produced by a chance arrangement of eddies of the dimensions to be expected according to modern theories with anything like the frequency observed, and he has found the question most puzzling.

The distribution of wind velocity in the lower levels makes it unlikely that a large part of the departures from the normal rate of ascent is due to genuine descending currents. It seems probable that when currents differing considerably in velocity and direction overlie one another, vortices may be produced which have horizontal axes, move parallel to the surface of discontinuity and have considerable permanence of form. Similar conditions may hold also, at times, near the ground surface. In such cases, if the eddy velocities are of the right magnitude, the chances of the balloon remaining for some minutes in the descending currents might be considerably enhanced. Evidences of such an effect have been observed up to considerable heights above the surface.

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At times there are, doubtless, genuine descending currents of considerable velocity, probably associated in most cases with inclined surfaces of discontinuity. The discontinuity need not be very pronounced. Indications of slight discontinuities and downward currents are sometimes seen in strato-cumulus when a cloud mass has a very sharp forward boundary beyond which is clear sky.

In anticyclonic weather there must be a descent of air, and low rates of ascent have been observed at a number of places.[1] If, however, the whole effect is due to vertical currents, the air must be descending much more rapidly than accords with the computations of Sir Napier Shaw[2] and others. It is suggested that the balloon has actually a lower rate of ascent in air with a low lapse rate than in that in which the adiabatic lapse rate has been established. A slight effect of the kind would be produced through the hydrogen cooling more rapidly than the surrounding air and the balloon consequently losing buoyancy. More important than this, however, is the fact that the balloon disturbs a considerable volume of air and probably drags several times its own volume after it. This would require the expenditure of considerable energy in a stable atmosphere, and a decrease in the ascending velocity would result. This last would appear to be a factor of importance in connection with the motion of aircraft. The absence of turbulence in a stable atmosphere would also tend to produce a reduction in the rate of ascent of a pilot balloon. The effect of stability may be enhanced in the case of the Melbourne ascents owing to the small dimensions of the balloons used.

It is possible that variations in wind velocity and direction with height may seriously affect the rate of ascent through their influence on the nature of the air envelope and the wake of the balloon. By adding weights to the neck the stability of the balloon in the air can be so increased that the value of q in the Dines formula needs to be increased by ten per cent. to give the correct ascending velocity. It is obvious, therefore, that anything which distorts the wake of the balloon may produce some effect on the rate of ascent.

The following are the conclusions which have been reached regarding low rates of ascent of pilot balloons :—

(1) Low rates of ascent are very frequent near the surface at Melbourne and large departures from normal are sufficiently numerous to constitute a serious practical disadvantage to the one theodolite method.

(2) These low rates are to a large extent fortuitous and due to the descending portions of eddy currents. Anything which causes increased turbulence, therefore, although it tends to increase the mean rate of ascent, increases also the chances of a low rate.

(3) The distribution of eddies may under certain circumstances, *e.g.*, near the ground or near a surface of discontinuity, favour the chances of a balloon being caught and held in them for relatively long periods.

[1] Sutton, L. J., "The Upper Currents of the Atmosphere in Egypt and the Sudan." *Cairo, Physical Department*, Paper No. 17.

[2] Sir Napier Shaw, "The Air and its Ways."

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(4) Genuine downward currents will also, at times, play their part in producing low rates of ascent. The descending currents may be:—
  (*a*) the counterpart of rapid upward convection currents,
  (*b*) on the cold side of an inclined surface of discontinuity,
  (*c*) due to general subsidence in an anticyclone.

(5) Departures of the rate of ascent of balloons from normal are not due, entirely, to vertical air currents. Three suggested causes of abnormal rates of ascent are:—
  (*a*) stability in the atmosphere, as a result of which any vertical movements of air will be resisted;
  (*b*) variations of wind velocity and direction with height, which will result in the distortion of the wake of the balloon;
  (*c*) variations in the characteristics of the balloon as regards shape, size and internal pressure.

I wish to express my thanks to the Commonwealth Meteorologist for permission to publish the paper and for facilities in connection with its preparation.

DISCUSSION.

Mr. D. BRUNT wished to congratulate Dr. Kidson on the excellent results he had obtained when he was obviously working with rather indifferent materiel. He had used a range-finder, one of the most difficult instruments to use. He (Mr. Brunt) had tried it some years ago and found that for accurate results it was not suitable. It was not easy to keep the pilot balloon in the field of view, and it was difficult to take observations rapidly. Yet he thought the Society could accept the results which Dr. Kidson put forward as substantially accurate. One did find large ascending and descending currents in the atmosphere. At Shoeburyness the method of two theodolites had been used for ten years, and he hoped the observations would be analysed in the near future and perhaps presented to the Society. Very large descending currents had been found for which it was difficult to find a physical explanation. In the normal way one thought of ascending currents as being strongly localised, with the compensating descending currents spread over a wider area, and in the nature of a settling down of portions of the surrounding air. Some of their pilot balloon observations had shown signs of very strong vertical currents, some of which were greater than any reported by Dr. Kidson. It was not unusual to find a pilot balloon which should have gone up 500 ft. in the first minute going up 1,500 ft., nor was it unusual to find a balloon only going up 250 ft. in the first minute instead of 500 ft. So far these results are not abnormal. Ascending currents may occur in the middle of anticyclones, and these cannot in all cases be explained as due to topography. At Larkhill, when observations were taken in a wind blowing up a slope, it was found, after the first minute, that the balloon in several cases got into strong descending currents in the middle of an anticyclone. In the middle of a cyclone one may find descending currents. [Added later: These observations bring out very clearly the need for carrying out pilot balloon observations by a method which does not assume a uniform rate of ascent.]

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Mr. F. J. W. Whipple referred to the idea mentioned in the paper and also by Mr. Brunt that it was natural to think of convection as implying the ascent of air in localised currents and the gradual settling down of air to take its place. He (Mr. Whipple) would have liked to know whether the people who shared that view were guided by general physical principles or by observations. In a pot standing over a stove warm water went up and cool water went down, and he did not feel any impulse to suppose that the ascending and descending currents were very dissimilar. The same problem was presented by the atmosphere.

He regretted that the observations discussed in the paper did not include more cases of more than one ascent on the same day, as it would have been interesting to know how frequently strong descending and ascending currents occurred within a short interval. There was one striking instance of descending and ascending currents in a single ascent; on October 19, 1923, the upward progress of the balloon practically ceased for two or three minutes; after being driven down a little, the balloon spurted up at a great rate.

Mr. Brunt replied that he had only pointed out that the prevailing idea among meteorologists was that ascending currents were stronger than descending currents, and he had neither justified nor condemned this idea. It is natural to regard ascending currents as being produced by strong heating of a portion of the earth's surface, the air over this portion being heated and rising, its place being taken by air drifting in from all sides and a general settling down of the air in the immediate neighbourhood. This is a different phenomenon from that which occurs in the pot discussed by Mr. Whipple. The circulations of fluid in the pot are closed, while those in the outer air are not closed. He did not regard the phenomena in an enclosed pot as typical of those which occurred in the atmosphere.

Dr. E. Kidson, in reply to the discussion, writes :—

A simple device has been adopted at Melbourne for mounting the rangefinder on the legs of a theodolite. Having a steady support at a convenient height, an experienced observer can use the rangefinder without difficulty and with all the necessary accuracy. The balloon is easily picked up during the first few seconds after release and should not thereafter be lost sight of. With a small rangefinder, at any rate, the limits as to range and accuracy are set by the instrument itself. Within these limits, I have no doubt that, on the average for all conditions, better results are obtained than with the two-theodolite method. The limitations of the latter method are not always fully realized.

The heating in the pot referred to by Mr. Whipple is being carried out with much greater intensity than happens in normal conditions in the air. Nevertheless, movements such as he describes may take place within a few feet of the ground. When masses of air of dimensions comparable with those of the eddies dealt with in G. I. Taylor's theories are concerned, however, the processes are different. It is not easy to understand how the potential temperature of air at a height above the ground can be rapidly lowered and the air consequently fall as a localized current. In the paper, rapid descending currents are not ascribed, in general, to the descent of cold air but to the mechanical effect of eddies. The ascending currents listed, on the other hand, show a definite rise of air that has been heated at the ground surface. Mr. Whipple is mistaken with regard to the ascent of October 19, 1923. The process

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he describes is quite a possible one, but in the case quoted the normal rate of ascent was never reached. The examples given all show persistent effects.

I should have liked to see some discussion in reference to the rate of ascent of the balloon through its surrounding air, particularly as regards the effect of stability. I consider this a very important question.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 19, 1926.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society :—

WILLIAM ERSKINE BAIN, Lieut. R.N.R., Marine House, Chandballi, Orissa, India; and

OTTO HOLSTEIN, Major (retired) U.S. Army, Casilla 155, Trujillo, Peru.

June 16, 1926.

At this *Ordinary Meeting* three papers were read and discussed. There were no candidates for election to Fellowship.

CORRESPONDENCE AND NOTES.

Winter Thunderstorms in the British Isles.

Mr. S. Morris Bower, continuing his investigations on winter thunderstorms in the British Isles, furnishes the following details concerning the storms experienced during the period Jan. 1, 1926, to Mar. 31, 1926.

Thunderstorms occurred somewhere in the British Isles on 49 out of the 90 days considered, a figure eight days less than that obtained during the same period in 1925 but almost the same as that for 1924.

The following table shows their division among the several countries:

1926.	Eng. & Wales.	Scotland.	Ireland.	British Isles.
Jan.	17	4	15	21
Feb.	11	6	5	13
Mar.	9	11	6	15
Year	37	21	26	49

Reports this year were received from 1,356 observers in England and Wales, from 61 in Scotland, 56 in Ireland, and from 14 observers on the Continent. Included in these figures are 85 observers from light-houses and light-vessels.

Mr. Bower, who is continuing the investigation during the present winter and is extending the period to cover the six months from October to March inclusive, would be glad to receive reports as before, giving particulars as to time of occurrence, severity, wind and temperature, together with any other particulars likely to be of interest.

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A Comparison of the Minimum Temperatures as recorded by Grass Minimum Thermometers set over Shingle and Grass at Felixstowe.

For more than a year minimum temperatures over shingle have been recorded at this station in addition to the ordinary readings taken over grass. The following table and remarks are for the year March 1925– February 1926.

The two thermometers have been within 25 yards of each other on the same piece of level ground, one being set over grass (with shingle as subsoil) 15 yards to the N.W. of the Meteorological hut, and the other 10 yards S. of the hut. It should be pointed out that during this period the grass minimum thermometer was surrounded by a protective wooden fence which was sufficiently skeleton and far enough away not to affect the readings in any way.

The time and method of setting, etc., have been the same throughout (set at 18.00 G.M.T. and read at 07.00 G.M.T.), and the two sets of readings are directly comparable. The thermometers were also suitably marked for easy identification and as a safeguard against confusion.

The table gives the mean daily differences in degrees Fahrenheit between the readings of both instruments for each month and the year.

TABLE I.—TABLE SHOWING THE MEAN TEMPERATURE DIFFERENCES (SHINGLE-GRASS) FOR TWELVE MONTHS AND THE YEAR AT FELIXSTOWE FOR THE PERIOD MARCH 1925—FEBRUARY 1926 (INCLUSIVE), WITH FIGURES AND NOTES ON THE MAIN FEATURES OF THE WEATHER.

Month.	Mean daily temperature differences. (shingle-grass).	Differences from normal of means.				Remarks.
		Temperature.	Rainfall.	Rain Days.	Daily sunshine.	
1926.	°F.	°F.	mm.	No.	hrs.	
Jan.	−0.7	+0.9	+10	+2	−0.2	Wet and warm apart from a little snow.
Feb.	−0.4	+5.3	+20	+1	−1.0	Mild, foggy and dull.
1925.						
Mar.	+0.1	−0.5	−16	+2	−1.0	Cool with N. winds and dry. A week's snow.
April	+0.7	+0.1	+ 8	+6	−1.1	Wet and dull. Moderate temperature.
May	+0.3	+2.7	− 2	0	+0.4	Warm and thundery. Bright periods.
June	+0.4	+0.9	−39	−9	+1.2	Fine and warm. Abnormally dry.
July	−0.1	+1.6	− 6	−2	−1.0	Warm and thundery. Fair.
Aug.	+0.2	+0.8	+13	+2	−1.8	A dull, wet month.
Sept.	−0.2	−3.2	+21	+6	−1.9	Cool and windy. Dull.
Oct.	−0.2	+1.2	− 9	−2	0	Normal October weather. Fine at first.
Nov.	−0.4	−2.3	− 7	+1	+0.4	Cool, dry and sunny.
Dec.	−0.8	−2.1	− 2	−3	+0.7	Cool and sunny with snow. Warm 26th-31st.
Year	−0.1	+5.4	− 9	+4	−5.3	Fairly normal year. Dry June. Wintry Dec.

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These differences have been plotted against time. They give a fairly smooth and consistent curve as shown by the continuous line in the graph.

From the table it is seen that the differences (shingle-grass) divide up into two distinct periods in which there is a plus difference and a minus difference respectively. The former difference occurs in the six months March-August and the latter in the six months September-February. This means that there is a higher mean minimum temperature over the shingle than over the grass during the period March-August, and *vice versa* during the period September-February. The one exception to these statements is the July reading, which gives a small minus difference where, from the general run of the figures, one would have expected a plus one.

The results would appear to establish that on the average :—

(1) At night during the six months' period March-August the air directly over shingle was rather warmer than that over the grass.

(2) At night during the six months' period September-February the air directly over grass was warmer than that over shingle.

(3) At night for the year as a whole the air directly over shingle was slightly colder than over the grass.

The explanation of the results involves several factors, but no doubt the main one is the radiation effect in relation to long and short nights. Shingle takes up and gives out heat quicker than turf. During the period of long days and short nights (viz., March-August) the time of taking up heat is longer than the time of giving it up, and the actual balance of heat at night is with the shingle. During the period of short days and long nights (viz., September-February) the balance is with the grass.

The way in which the length of day seems to regulate the temperature differences as between grass and shingle is most easily shown on the graph, the dotted line in the graph giving the difference from Mean Day in hours at Felixstowe as taken from the *Book of Normals*.

C. W. LAMB.

Felixstowe,
September 8, 1926.

Floods in Yugoslavia.

Towards the end of June and throughout the month of July, 1926, widespread floods were prevalent in many parts of Europe. Early in July heavy thunderstorms broke throughout Germany. In the Berlin district much damage was done to crops, while in other parts of Germany excessive rainfall caused considerable damage to property and loss of life. There was also extensive flooding in the Paris suburbs and in Switzerland.

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It was in Yugoslavia, however, that the worst floods occurred, both as regards intensity and duration. Indeed, the widespread havoc which they caused was little short of a national calamity. From the end of June to July 21 different parts of the country suffered in varying degrees. Large tracts of southern Serbia and parts of Hertzegovina were under water by July 1. Nish, Veles and Pirot were flooded, and the crops were ruined over a considerable area. In the basin of the Danube the situation became very serious on the 4th, as crops were being destroyed on the eve of the harvest. The Baranya, in the corner between the Drave and the Danube, was particularly afflicted and the royal residence at Belye was under water. Parts of Belgrade were inundated by the overflowing of the Danube and the Save.

Fresh floods occurred about a fortnight later. An unusually intense hailstorm broke over Montenegro and practically destroyed the village of Rugovo. Many of the hailstones are reported to have weighed nearly 10 ozs. With the destruction of the village 40 persons were killed and several thousand sheep and cattle drowned. The Danube and the Drave again overflowed their banks. The water was 60 feet deep over the Baranya, and more than 2,000 gazelles and countless grouse were drowned. Up to this time the damage was estimated at £7,500,000, and so urgent was the necessity for relief that the salaries of state officials were immediately reduced by amounts varying from 5 to 50 per cent.

In spite of the greatest precautions many dams burst their banks, and by the 20th the waters of the Danube had flooded large areas round Novisad and Bogoyevo, between the Hungarian frontier and Belgrade. Traffic came to a standstill on many railway lines and much damage was done at Valyevo and Lornitza, where bridges were broken and crops destroyed. The inhabitants were compelled to take refuge in tents on higher ground.

In the Batchka and Baranya districts houses were completely or partially destroyed; cattle, pigs and poultry were swept away; and general damage was caused to railways, roads, bridges and factories. The damage to crops alone in these districts was estimated at £1,200,000, an area of approximately 264,000 acres having been completely inundated.

It is interesting to follow the changes in the pressure distribution which were primarily responsible for these floods. The meteorological situation over western Europe towards the end of June was dominated by a large anticyclone which spread eastwards from the Atlantic. By June 29 this anticyclone was centred over the North Sea, covering the British Isles and extending its influence over France and Central Europe. An area of relatively low pressure over Spain and the Mediterranean was maintained, and a small secondary development, which was located over northern Italy on the evening of the 29th, moved north-eastwards and began to grow deeper. By the morning of the 30th this secondary was centred over northern Yugoslavia, where it remained practically stationary for several days, producing the heavy rains which caused the floods in Serbia, Hertzegovina, and the Baranya.

On July 3 the centre moved slowly eastwards to the Black Sea and the weather became temporarily fairer. The anticyclone had now moved to a position between Iceland and Scandinavia and pressure continued relatively low over Spain, Italy and south-eastern Europe. On the 10th this low pressure system gradually filled up and an anti-

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cyclonic centre shifted slowly from the Bay of Biscay to Germany, thereby controlling the weather over the larger part of Europe. By the evening of the 14th the anticyclone, under the influence of a deep depression which was moving south-eastwards across Norway to the Gulf of Finland, gave way completely, and on the morning of the 15th Central and south-eastern Europe were once more regions of comparatively low pressure. A series of shallow depressions quickly formed and the situation became very favourable for the development of thunderstorms. Over Yugoslavia the storms were intense, particularly in Montenegro, where the severe hailstorm referred to above did so much damage.

By the 17th an anticyclone had again developed over Germany, but depressions from the Atlantic moving eastwards across the British Isles soon compelled it to give way, and from the 19th to the end of the month secondaries continued to cross southern Germany and the Balkans, causing further thunderstorms and heavy rain with consequent renewal of the floods in south-eastern Europe.

Note on the Rain of 1926, May 14th, over Ceylon.

When the south-west monsoon is fully established over Ceylon, the heaviest rainfall is usually on the windward slopes of the main hills, but during the initial development of the monsoon there is usually a stage at which the low country along the west and south-west coast receives the heaviest rain. This admits of explanation in general terms by saying that the adolescent monsoon current can be checked and made to deposit its moisture by the slight opposition offered by coastal friction, and convection effects in the low country, whereas when at its full strength a month later the monsoon current is superior to such slight opposition and does not deposit much rain until it meets the more rigid opposition provided by the hills themselves.

This year the first pressure gradient from somewhere near the south-west occurred on May 13, and the attached diagram shows the resulting rainfall on May 14. It brings out the way in which the rainfall was both intense at the coast, and was limited to the neighbourhood of the coast, but a further point is brought out when the distribution along that coastal strip is considered.

If we consider a mass movement of air being checked by the opposition of a range of hills, there will clearly be both a banking up on the windward side and a certain amount of forced ascent, but there will also be a tendency for the air to try to go round instead of over. Hence in this case near the northern limit of the hills the advancing air will tend to be displaced to the left, and air so displaced outwards will tend to interfere with the air in the adjacent streamlines which, when over the ocean, had been on its left and travelling on a parallel line. Incidentally it may be mentioned here that at Colombo "west-south-west monsoon" would be a more precise description of what is commonly and conveniently known as the "south-west monsoon."

The heaviest rainfall on May 14 was in the Nattandiya district. The gauge at Wahalapitiya Estate led with 18 inches in 24 hours, Horakele Estate being second with a little over 15 inches. It is therefore rather striking to find that a streamline from west-south-west to east-north-east through Nattandiya forms an almost perfect tangent to the 3,000 feet altitude contour, and it is also interesting to identify the

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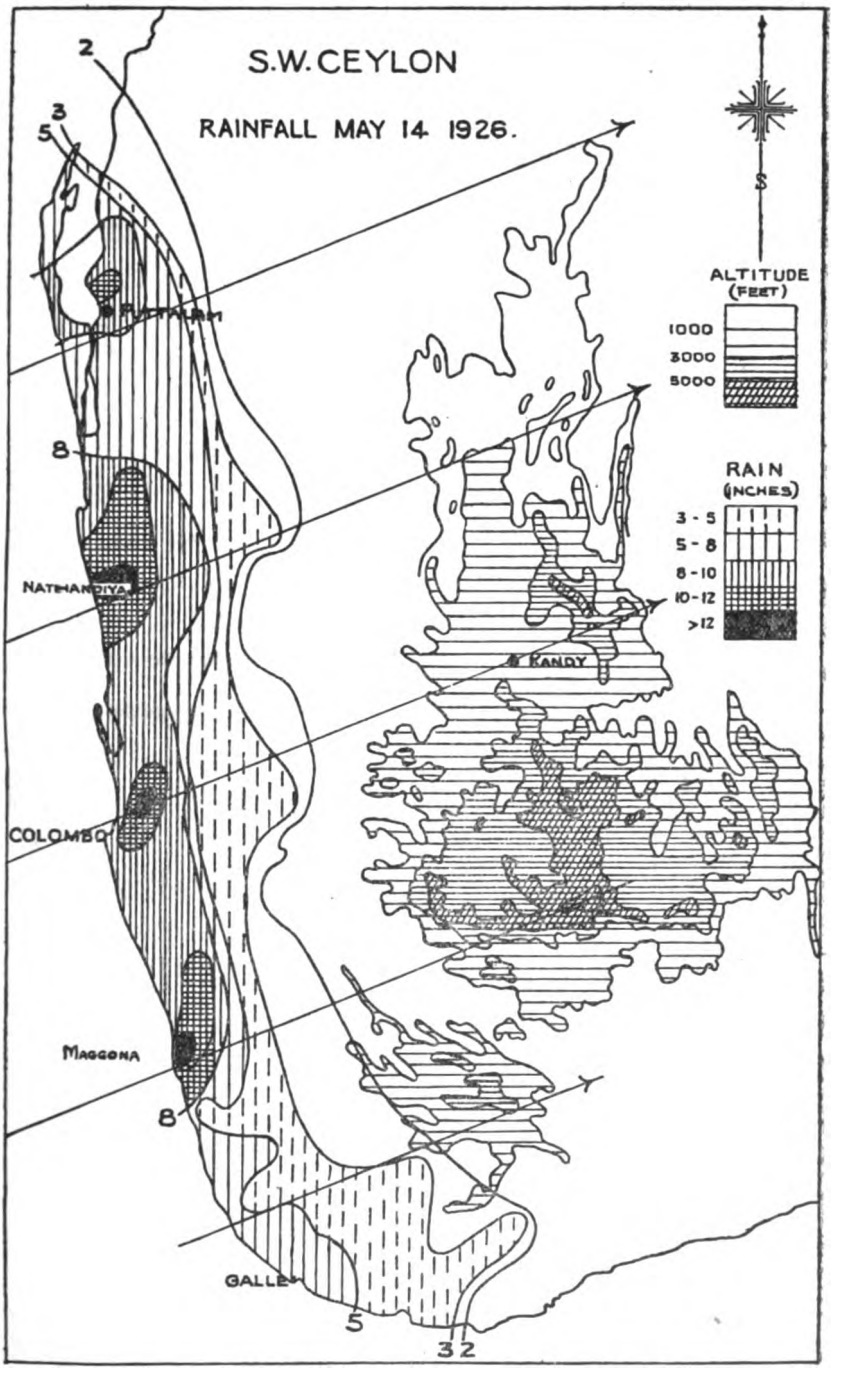

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other fluctuations along the coast in terms of an altitude section of the hills at right angles to the advance of the monsoon current, and to see the way in which the heaviest rain at this " adolescent " monsoon stage corresponds to what may be called the edges of that cross section, whereas in the fully-developed monsoon, when the orographical effect is more obvious, it is not the edges but the main masses of the mountains that are in line with the heaviest rain.

Thus on May 14 the next highest figures after the Nattandiya district were at Maggona (13 inches) and a line from WSW through this station crosses the 7,000 feet contour close to a place known as " World's End View "—a sufficiently descriptive name to require no explanation. Between these two specially wet areas and just north of Colombo was another area of over 10 inches which apparently corresponds to the gap in the hills near Kandy.

North of Puttalam there was yet another area with over 10 inches, quite close to the extreme northern limit of the 3 inches rainfall isohyet. This appears to be in line with the extreme northern limit of the main hills. To bring out this point the northern part of the 500 feet contour has been inserted, though this contour has not been continued further south where it would be in most cases close to the 1,000 feet contour.

At the extreme south, though the rainfall quantities are not quite so great, there appears to be a bending of the isohyets corresponding to the southern limits of the Deniyaya hills which show on the map as a small anvil-shaped closed contour of 3,000 feet.

Another point in connection with this heavy rain may be of possible interest to any who are interested in the subject of tropical depressions. There are abundant examples in Ceylon of the fact that the coming of a depression is heralded by a rise in temperature at the upper hill stations. In this case there was no such rise, and this fact, as well as the distribution of rain, makes it seem certain that we cannot describe the rain of May 14 as due to a depression. On the other hand, several of the stations concerned report notable fluctuations in wind, while I am indebted to Mr. T. W. Hockly, who was afloat between the Maldives and Colombo on May 13, for news of very strong wind off the west coast on the 13th and 14th, which followed sharply on an absolute calm.

Further, by May 20 there was a very definite depression with centre at about 13° N. 87° E., whose subsequent course was roughly directly away from Ceylon. All this, coupled with the general ideas of the depressional front of a monsoon advance which date back to the time of Sir John Eliot, seems to suggest that the structure of what was experienced was that a general advance of air from the SW (or WSW) formed a number of small eddies about May 13-14 in which it was probably assisted very materially by the unequal resistance of various parts of the Ceylon hills. The monsoon front of May 14 may thus be considered as built up of a number of " bubble " depressions, none of which were extensive enough to show the temperature effects that occur over Ceylon in a well-developed depression, while the observations are not numerous enough to show how far they existed individually on a small scale. These " bubble " depressions gradually coalesced over, and north-east of, Ceylon to form one definite and more powerful depression by May 20.

In this connection it is worth noting that a very similar experience occurred in 1920, when heavy rain at Galle and neighbouring stations on April 26 fits in with the idea of bubble depressions coalescing to form one main depression in the Bay by May 1. A. J. BAMFORD.

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Discussions at the Meteorological Office.

The meetings for the discussion of recent contributions to meteorological literature will be resumed at the Meteorological Office during the session 1926-27. The meetings will be held on alternate Mondays at 5 p.m., beginning on Monday, October 11, 1926.

October 11th (MR. J. S. DINES)—

Dobson, G. M. B., and **Harrison, D. N.**—Measurements of the amount of ozone in the earth's atmosphere and its relation to other geophysical conditions. *London. Proc. R. Soc.*, **110** (A.), 1926, pp. 660-693.

October 25th—(MR. E. G. BILHAM)—

The measurement of humidity in closed spaces. *Food Investigation Board Special Report*, No. 8.

November 8th (MR. E. TAYLOR)—

Mügge, R.—Über Temperaturschwankungen in der Stratosphäre und die hochreichenden Antizyklonen. *Met. Zs.*, **42**, 1925, pp. 389-394.

November 22nd (MR. N. K. JOHNSON)—

Richardson, L. F.—Atmospheric diffusion shown on a distance-neighbour graph. *London, Proc. R. Soc.*, **110** (A.), 1926, pp. 709-737.

December 6th (MR. R. H. MATHEWS)—

Nukiyama, D.—On the theory of monsoon rainfalls in the Far East. *Tokio, Japan J. Astr. Geophys.*, **2**, 1924, pp. 75-90.

The dates for subsequent meetings are as follows:—

1927. January 17 and 31; February 14 and 28; March 14.

OBITUARY.

Rev. H. A. Boys, M.A.

We learn with regret that the death of the Rev. H. A. Boys occurred at St. Mary Bourne, Hampshire, on July 31, 1926.

Born on November 18, 1841, he was educated at Uppingham and at Emmanuel College, Cambridge, where he was Johnson and Thorpe Scholar. He took honours in mathematics, classics and theology. Ordained deacon by Bishop Magee, a life-long friend, his health broke down in 1870. After many years spent in the Mediterranean he returned to England in 1890 and accepted the benefice of Easton-Mauduit. Six years later he became Rector of North Cadbury, Somersetshire, a living which he held until 1921. On his retirement he went to live at St. Mary Bourne, where his brother, Prof. C. V. Boys, F.R.S., had already made his home.

Meteorology was his hobby and great delight for over 60 years, and he was the prime mover in the formation of the Mid-Wessex Rainfall Association. He was an ardent cyclist and continued to ride till past his 80th birthday.

He was elected a Fellow of this Society in 1900.

Captain M. H. Clarke, O.B.E.

The death of Captain M. H. Clarke, Chief Surveyor and Emigration Officer to the Marine Department of the Irish Free State Ministry for Industry and Commerce, occurred suddenly on August 9, 1926, from cerebral hæmorrhage, following on over-exertion while cycling.

Captain Clarke, who was a well known and popular figure in Dublin, joined the Board of Trade in London 27 years ago after a successful

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career in the Merchant Service. In 1917, he became principal officer in Dublin and later was awarded the O.B.E. for his services during the war.

He was a Fellow of the Royal Geographical Society and was elected a Fellow of this Society in 1900, serving on the Council during the years 1907-8.

Captain S. G. Dale.

We regret to learn of the death of Captain S. G. Dale, who died suddenly at sea from heart failure.

He was born in 1870, and in 1882 was apprenticed to the sailing ship *Flying Venus*. Transferring to steam in 1889, he was three years later appointed Chief Officer of *Norse King* and in 1898 he became master of the s.s. *Tagus*. He continued as master of various ships until his death on August 9 on board the s.s. *Ribera*. He was buried at sea the following day, having maintained throughout his whole sea experience a record free from accident of any kind.

He was elected a Fellow of this Society in 1917.

Sir Peter Lang, M.A.

The death of Sir Peter Lang occurred at his residence, Mansfield, St. Andrews, on the night of Monday, July 5, 1926.

Born in Edinburgh in 1850, he graduated M.A. in 1872 at Edinburgh University and was chosen by the late Prof. Tait as his assistant. From Edinburgh he went to St. Andrews as professor of mathematics. Here he took a special interest in students' affairs, being instrumental in forming the University Athletic Association. He held the rank of colonel in the 1st Fifeshire Volunteer Artillery, and was knighted on his retirement in 1921 in recognition of his educational and military services. He was a man of many parts and endeared himself to all connected with St. Andrews University.

He was elected a Life-Fellow of the Scottish Meteorological Society in 1886.

Lord Lyell.

Baron Lyell of Kinnordy died at Kinnordy, Kirriemuir, Forfarshire, on Saturday, September 18, 1926, at the age of 75.

A nephew of Sir Charles Lyell, Bt., and a grandson of Leonard Horner, F.R.S., he showed a decided scientific bent, and after studying at Berlin University he graduated at London University, and was for a time professor of natural science at the University College of Wales.

In 1885 he became M.P. for Orkney and Shetland and in 1894 was created a baronet, being raised to the peerage twenty years later.

He was elected a Fellow of the Scottish Meteorological Society in 1909.

Mr. Carl Stoeckel.

The death of Mr. Carl Stoeckel occurred in November last in Norfolk, Connecticut, U.S.A.

He was born in New Haven on December 7, 1858, and was educated under private tutors in America and Europe. He received an honorary A.M. degree at Yale in 1905.

Both he and Mrs. Stoeckel were great patrons of the arts and to their large music hall, built in the grounds of their estate, they attracted the highest American and European talent. At their festivals many

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original works were conducted by their distinguished composers. Mr. Stoeckel was, too, a member of many learned societies in America, and was elected a Fellow of this Society in 1910.

Mr. A. S. MARRIOTT.

We regret to learn also of the death of Mr. A. S. Marriott, who died some years ago. He was elected a Fellow of this Society in 1887.

REVIEWS.

Extraits des Mémoires de Lavoisier concernant la météorologie et l'aéronautique. Extraits publiés par les soins de l'Office National Météorologique de France. Paris (Etienne Chiron, Editeur) [1926]. 8vo. Pp. 4 + 232, portr. 30 fr.

Alongside the fine series of monographs in which the results of new meteorological researches are set out, the National Meteorological Office of France has undertaken the collection and republication of the more important works of the French founders of meteorology, and has commenced the series with extracts from the memoirs of Lavoisier. It is as a chemist, and especially for his discovery of oxygen, that Lavoisier is best known, but those were the days before specialists, and nothing connected with the atmosphere came amiss to him. The principal memoirs contained in the present volume deal with the following subjects: the formation and constitution of the earth's atmosphere; a series of papers on the cold winter of 1776; a report on the fire-balloon of the brothers Montgolfier; various memoranda on the construction of barometers of different types; rules for weather forecasting from changes of the barometer. From the latter we learn that even in those days (1790) the legends fine, stormy, etc., inscribed on barometers had already been stereotyped, and are described by Lavoisier as only moderately useful, "as it is less the height of the column of mercury than its changes that must be considered." There is also a history of the anemometer, a report on a supposed thunderbolt, which turns out to have been a specimen of iron pyrites struck by lightning (most "thunderbolts" have not even that amount of justification), a report of tests on a "hygroscopic youth," and the determination of heights by the barometer. It will be seen that Lavoisier lived in times fruitful in meteorological discoveries, and that his own share in them was not small. Almost every subject that he touched had its own problems; in investigating the cold of 1776 he found it necessary to begin by verifying the different thermometers in use, and he went on to revise the specifications for an accurate instrument. Similarly the account of the fire-balloon closes with a discussion of the possible use of gases lighter than air.

One could have wished that the volume had been preceded by a short biographical note. The series of extracts closes abruptly with a number of papers dated 1790, and it would help the reader to form a just opinion of Lavoisier's scientific attainments were he told how at this point began the Reign of Terror, and how in 1794, at the comparatively early age of fifty and presumably at the summit of his powers, Lavoisier's work was cut short by the guillotine.

C.E.P.B.

Gerlands Beiträge zur Geophysik. Edited by Prof. V. CONRAD. Band **15**, Heft 1. Leipzig (Akademische Verlagsgesellschaft), 1926. Pp. iii + 89 + 3, 20 figures in text and one plate.

This publication, which had a continuous existence from 1887 to 1918, has made a welcome reappearance under the editorship of Prof.

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Conrad, of Vienna. The previous volumes have been reprinted, complete sets of which, with three supplements, can be obtained, price 400 Reichmarks.

In the present number, meteorology with its various ramifications is worthily represented. A paper by Anders Ångström on "Energy supplies and temperatures in different latitudes" is followed by one from the pen of Dr. Chree on "Magnetic disturbance and the magnetic characterization of days," in which are discussed the various criteria proposed for disturbance. A comparison is made of the results derived from the daily range and hourly range for two Antarctic stations for two months of 1912. The causes of the variation in electrical potential gradient are dealt with in a paper by Albert Gockel, while seismology is represented by contributions on the velocity of earthquake waves in the outer layers of the earth's surface and the depth of earthquake foci, and Prof. Sandström deals with an ambiguity of the meteorological influence of the Gulf Stream. A summary in Esperanto of each paper, printed at the end of each number, makes an interesting addition.

First Report of the Commission appointed to further the study of Solar and Terrestrial Relationships. Paris (Etienne Chiron), 1926. 8vo. Pp. 202. English and French text.

The proverb "What is everybody's business is nobody's business" is as true in science as it is in other human activities. The phenomena on the sun and the phenomena on the earth make up very nearly the total experience of humanity, and science may be said to be almost exclusively occupied in studying some one or other of these phenomena. The International Union for Astronomy has a large part of its activities devoted to studying the phenomena on the sun, while the International Union of Geodesy and Geophysics devotes its whole time to studying the phenomena of the earth. Yet it appears to have been the business of no one—at least, no international union—to study the relationships which exist between the phenomena on the sun and the phenomena on the earth. Realizing this important defect in their organization, the International Research Council appointed a special International Committee under the chairmanship of Prof. Sydney Chapman "to further the study of solar and terrestrial relationships." The Committee was appointed in June 1924, collected twenty notes and memoranda from the world's greatest authorities on the subject, met in July 1925, presented its report to the International Research Council in the same month, and finally published the report with the notes and memoranda in French and English early in 1926. It is seldom that an International Committee produces such an important piece of work in such a short time.

The Report commences with a statement of the principal terrestrial phenomena which are definitely known to be affected by changes in the sun; these are (*a*) the magnetic state of the earth and earth currents, (*b*) aurora, (*c*) meteorological and climatic changes. The Committee concluded that atmospheric electricity and radio-telegraphic transmission "are not improbably affected by solar changes"; while the amount of ozone in the upper air, the extra-polar auroral light, high-level atmospheric absorption, penetrating radiation in the atmosphere and the light of the night sky "are sufficiently likely to be affected by solar changes as to require further investigation from this standpoint." In a similar way the phenomena on the sun are classified as to whether they are definitely known to affect terrestrial phenomena, whether they probably do affect terrestrial conditions, and whether they warrant further investigation because they might do so.

The Report then goes on to discuss these relationships in detail and to make suggestions as to the lines along which international research

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should be guided. As it will be of considerable interest to Fellows of the Royal Meteorological Society to know the conclusions of the Committee with regard to meteorology, the following paragraph from the Report headed "Solar Relationships with Meteorology" is reproduced:

(10) Several significant correlations have been established between mean sunspot numbers and terrestrial temperature, rainfall and barometric pressure.

The existing supply of meteorological data probably suffices for the further investigation of such relationships, but there is great need for more solar data.

The regular detailed observation of (*a*) the amount and spectral distribution of the total solar radiation, and (*b*) of the absorption of solar radiation in the earth's atmosphere, is of primary importance. The work of the Smithsonian Astro-physical Observatory in this field at present stands almost alone. This work should be maintained, and new studies of a similar kind should be initiated at several further observatories well distributed in longitude round the earth, so that continuous overlapping records of the changes in solar radiation and its atmospheric absorption may be obtained.

(i) It is particularly desirable that regular observations of this kind should be made at observatories, preferably situated at a high altitude, in the following regions:—

(*a*) Australia.
(*b*) Europe.
(*c*) India.
(*d*) Indo-China.
(*e*) Japan.
(*f*) South Africa.

(ii) The Committee also wish to support the scheme for the observation of the amount of radiation received at the earth's surface in different parts of the world, which was recommended by Resolution No. 8 of the Meteorological Section of the International Union for Geodesy and Geophysics at Madrid in 1924.

(iii) The Committee consider it very desirable for the study of solar and terrestrial relationships that the amount of ozone in the upper atmosphere should be regularly determined by observing the absorption of the sun's ultra-violet radiation in the earth's atmosphere. This work can be carried on with comparatively simple apparatus. It is desirable that international co-operation in such observations should be arranged, and the Committee would draw the attention of the International Union for Astronomy to this need.

(iv) The Committee would suggest to the International Union for Astronomy that further observations of the brightness of the planets, and of the moon (especially when eclipsed by the earth) should be undertaken, in order to obtain additional data concerning solar variability, for comparison with terrestrial data.

The twenty memoranda which follow the Committee's Report are very important contributions to knowledge of solar and terrestrial relationships and will prove a very valuable record of the state of knowledge on this subject in 1925. The Committee has also included in the Report a valuable summary of the literature from 1914 to 1924 on the relations of solar and meteorological phenomena, followed by a complete bibliography giving references to all the papers summarized. This summary and bibliography were prepared in the London Meteorological Office by Mr. C. E. P. Brooks and occupy 35 pages of the printed Report.

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Los Huracanes de las Antillas. By SIMON SARASOLA, S.J. Bogota, 1925. Pp. 171. Maps and diagrams. (Notar Geofisicas y Meteorologicas, Num. II.)

This is a study of the hurricanes of the West Indies from the Director of the newly-organized National Observatory of Colombia, dealing with a multitude of facts relating to these destructive visitations, together with the methods of forecasting thereof and current theories as to the origin of tropical cyclones in general. In fairness to the author we state that insufficient familiarity with the Spanish language has precluded a close perusal of this important publication, and we can only indicate its general scope.

The author points out that whereas temperate latitude cyclones occur most frequently in the cold months when Bjerknesian discontinuities of temperature and humidity are sharpest, tropical cyclones are most active in the warmer months, but he favours the view that the latter are more immediately connected with a conflict of air currents. In this connection it seems a pity that Father Sarasola, like other authors, takes no hint from the general geographical background of tropical cyclones which strongly support his view. Tropical cyclones occur mainly towards the margins of the tropics on the western sides of the oceans in later summer or autumn, precisely when and where one trade system having crossed the equator encounters currents from the opposite trade systems, and it is significant that in the South Atlantic, which is the one hurricane-free tropical ocean, the North-East Trade makes no seasonal migration across the equator. It is not yet known definitely whether anything analogous to Polar Front discontinuities occurs in tropical cyclones, but it seems likely that the two feeding currents often differ considerably in humidity if not in temperature.

The work on the whole, however, is conspicuous both for local detail in relation to the hurricanes of the Caribbean Sea and for an appreciation of the wider relationship of the subject, a good deal of attention being paid to the influence of solar activity on the weather. It is a valuable synopsis and will repay study. L. C. W. B.

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AN INVESTIGATION OF PERIODICITIES IN RAINFALL PRESSURE AND TEMPERATURE AT CERTAIN EUROPEAN STATIONS.

By D. BRUNT, M.A., B.Sc.

[Manuscript received May 19—Read November 17, 1926.]

1. INTRODUCTION.

The question of the feasibility of using the periodicities which are known to exist in meteorological phenomena, for the purpose of forecasting the weather in its wider aspects for any future time, has been raised from time to time during the past century. It was raised in a very definite form at the meeting of the British Association at Liverpool in 1923, by Sir Wm. Beveridge, who maintained that the use of periodicities afforded a very powerful weapon for forecasting. At that time it appeared to me that definite information as to the nature of the periodicities which occur in various meteorological phenomena was insufficient to permit of a final judgment on the question at issue. There were, it is true, a number of periodogram analyses available for certain isolated stations, but these were not of such a nature as to show with certainty what use could be made of them in forecasting.

In order to obtain a sufficient mass of information to decide this question, I undertook, with the concurrence of the Director of the Meteorological Office, to investigate twelve sets of data each extending over at least 100 years, for all periods above one year in length. The data selected were:—

(*a*) Rainfall at Milan, Padua, London and Edinburgh.
(*b*) Pressure at Edinburgh and Paris.
(*c*) Temperature at Edinburgh, Stockholm, London, Paris, Berlin and Vienna.

A number of these records were initiated in 1764, and it was therefore decided to choose for each record the 100 years commencing at 1764, or as near as possible to that date. Monthly means for 100 years were used in investigating the shorter periods, but for periods of over 10 years all the annual means which were readily available were used.

In connection with the choice of data, it was found that the number of records extending over 100 years was limited, and it is doubtful whether all these can be accepted with absolute faith. Long records of rainfall may be subject to changes of location of

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the raingauge, and to changes of exposure even when the location is unaltered. The growth of trees and the building of houses may affect very materially the exposure of a raingauge, and it is not usual to find notes of any such changes in the longer records. Again with regard to temperature, errors due to the thermometers, changing when the thermometer is changed, may have readily occurred in the older records, and it is certain that the exposures of thermometers have been changed from time to time. Some of the earlier temperatures were certainly recorded by means of thermometers exposed outside windows on the north side of buildings.

In the present investigation no attempt was made to find any corrections to any of the data used. The data used have in most cases been published by central meteorological offices, and are therefore assumed to have been put forward as the best available figures. Should any system of corrections to the data be evolved, it would be a simple matter to evaluate their effect on the periodicities which I have worked out.

The details of the methods of computation, together with the twelve complete periodograms are given in a paper entitled "Periodicities in European Weather."[1] In that paper are given all the numerical results derived, shown in tabular and graphical form, together with tables of all the data used, and graphs of 5-yearly totals or means of the data. As only a very brief discussion of the results was given there, it is proposed in the present paper to discuss in greater detail the results obtained, together with some comparison with the results obtained by other workers.

It may not be out of place here to make a few remarks on the general utility of periodogram analyses. If we consider, say, the temperature at one station, we shall find a well marked annual variation. When the annual variation is removed, by subtracting the mean January temperature from all the January temperatures, etc., we are left with a series of figures each of which represents the departure from the mean for a given month. A graph of these departures is usually an extremely irregular curve, but harmonic analysis will usually bring out certain underlying periodicities. A temperature record thus appears to be formed of the resultant of a number of waves, upon which are impressed apparently casual variations. The existence of these casual variations makes it impossible to state with absolute certainty the length, amplitude and phase of any one of the periodicities, unless the particular periodicity is a very outstanding one.

Each of the periodograms reproduced in the paper referred to above shows a very large number of peaks, but with no very outstanding peak. For this reason I am satisfied that the results there given are not of direct value for forecasting. Had any of the periodograms shown two or three outstanding peaks only, then the results could have been used hopefully.

It will be seen later that a number of periodicities enter into a number of the series of observations considered, with approximately the same phase of maximum. This is regarded as very strong evidence of the physical reality of these periods, which would

[1] *Phil. Trans. R. Soc.*, A, Vol. **225**, pp. 247-302.

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appear to be of the nature of periods of oscillation of the general circulation of the atmosphere.

In order to make quite clear the nature of the problems which face the searcher for periodicities, I have shown in Fig. 1 the deviations from their means for 1841-1919 of the monthly mean temperatures at Greenwich. It is seen that no obvious law or order of any kind strikes the eye on looking at the diagram.

2. Variations of Climate during the Intervals Considered.

The outstanding feature of the diagrams of 5-yearly totals of rainfall, or of 5-yearly means of pressure and temperature[2] is the extreme variability of the elements considered. It is mildly surprising, for example, to find that 5-yearly totals of rainfall at Padua can vary from about 3,000 mm. up to about 6,000 mm., or that London temperature averaged over intervals of five years, may vary from 47.5°F. up to 52°F. A few sample curves which are fairly representative, are given in Fig. 2. A brief note of the main features of the variations for each station is added.

i. *Milan Rainfall.*—The 5-yearly totals vary in an irregular manner between about 4,300 mm. and 6,100 mm., showing on the whole a slight tendency towards increase of rainfall. The highest total is that for the five years centred on 1812, and an examination of the annual totals shows that this was due to a sequence of three wet years in 1812-13-14, culminating in an annual rainfall of 1,574 mm. (about 63 inches) in 1814. Of this last total, 338 mm. fell in August and 234 mm. in November. The wettest month was November, 1839, with 349 mm. of rain.

ii. *Padua Rainfall.*—The 5-yearly totals show a greater range of variation than Milan, and it is notable that the peaks and dips in the curves for these two stations show little correspondence. At Padua, August and November 1814 had only normal or less than normal rainfall, but November 1839 had 162 mm., which is well above the normal for the month. The five years centred on 1772 gave the highest total rainfall at Padua, but gave a total well below the mean at Milan. The differences which are found in the rainfall records at Padua and Milan can probably be explained by the differences in the prevailing winds at the two stations. Thus the seasonal wind roses for Milan show that the prevailing wind is westerly in winter and south-easterly in the other three seasons. The seasonal wind roses for Padua show in autumn and winter a very marked predominance of northerly winds; in spring winds from east and south-east become more frequent than in winter; and in the summer winds from north and south-east are about equally frequent. The régime of winds is thus entirely different at the two stations.[3]

iii. *London Rainfall.*—The 5-yearly totals vary from 107 inches to 150 inches. At the end of the 18th century the 5-yearly totals were about 110 inches, rising to a maximum of 135 inches in the five years centred in 1822, then falling to a minimum of about 115 inches in the middle of the nineteenth century, after which

[2] *Loc. cit.*, pp. 273-275.
[3] *Vide* F. Eredia, "I Venti in Italia."

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there was another rise to a maximum of about 150 inches in 1875-9, followed by a fall to about 120 inches by the beginning of the present century. The general appearance of the curve is represented roughly by two waves of about 50 years each, superposed on a general tendency to increase.

iv. *Edinburgh Rainfall.*—Shows the same general trend as London rainfall, except that the minima in the Edinburgh curve are more marked.

v. *Edinburgh Pressure.*—The curve of 5-yearly means shows a general tendency to rise during the interval considered, with some irregular oscillations superposed.

vi. *Paris Pressures.*—The curve of 5-yearly means for Paris pressure shows a very striking trend. The value for 1760-64 was 759 mm., the highest mean recorded. After this there was a steady trend downwards to a minimum of 755.4 in 1815-19; and this was followed by a tendency to rise. The change of over 3½ mm., from 1760-64 to 1815-19, is too great to ascribe to errors of observation or to any accidental cause, and it appears to indicate a steady change of the mean pressure distribution. I have not been able to trace any other records of pressure extending as far back as 1760, in order to compare with the Paris records. Records of pressure at Oslo (Kristiania) for 100 years, commencing in 1816, have recently been published,[4] but they do not show any close resemblances in detail to those of Paris. These records indicated a well marked tendency to decrease of pressure during the last 40 years.

vii. *Edinburgh Temperature.*—The 5-yearly means of temperature at Edinburgh showed well marked minima centred about 1772, 1812, 1837 and 1860, the minima being from 1½ to 2°F. lower than the intervening maxima. After 1860 the oscillations were somewhat irregular.

viii. *Stockholm Temperature.*—The 5-yearly means here show considerably greater variability, being at times subject to oscillations of about 1½°C. in 10 to 15 years. On the whole there is a tendency downward from the middle of the eighteenth century to the middle of the nineteenth century, followed by a tendency to rise. The curve for Stockholm resembles somewhat the Edinburgh temperature curve with the oscillations much accentuated.

ix. *London Temperature.*—The curve of 5-yearly means, starting from 47.8°F. in 1765-9, rose rapidly to a maximum of 52° in 1780-4, after which there was a steady fall to a minimum of 48.3° in 1835-9, followed by a gradual recovery, which was checked in 1885-9, but afterwards continued.

x. *Berlin Temperature.*—The curve differs from that for London in that 1765-9 was the maximum (10.4°C.), which was followed by a sharp fall. The absolute minimum (8.0°C.) occurred in 1810-14, and was followed by a gradual rise. Still earlier records of temperature at Berlin indicate that the coldest 5-year interval was that centred on 1742, having a mean temperature of 7.9°C., while the 5-year interval centred on 1757 had the highest mean recorded, about 10.7°C.

[4] Birkeland, *Geofysiske Publikationer*, Vol. 3, No. 9.

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xi. *Paris Temperature.*—The curve of 5-yearly means bears a close resemblance to that for Berlin, except that the absolute minimum comes still earlier, in 1785-9 at Paris.

xii. *Vienna Temperature.*—The curve resembles that for London, even in its details.

The temperature curves for London, Berlin, Paris and Vienna have one marked feature in common. They all show their absolute maximum during the last half of the eighteenth century, after which they showed a steady drop of temperature for all four stations. The Edinburgh records do not show this feature. During the period when the temperature was falling over this wide area, the pressure recorded at Paris showed a steady decrease, while the rainfall at Padua also showed a steady decrease. All these factors have since shown a tendency to rise, but in no case has the earlier maximum been attained, and though our grandfathers may have suffered from colder weather than we now endure, our great great great grandfathers must have enjoyed milder weather than we.

In a paper, entitled, "Are the Seasons Changing?"[5] are given mean temperatures for successive intervals of 10 years from 1781 to 1920, for certain American stations. A graph of these figures (Fig. 2, curve 4) bears a remarkable resemblance to that of Padua rainfall for the same period. This suggests that the causes which produce the large surges of temperature or rainfall are effective over very considerable zones of the earth's surface.

I am not in a position to suggest the cause of the big changes which started in the last quarter of the eighteenth century. It may have been due to the decrease of polar ice, but data on this subject are lacking.

3. Periods Longer than Ten Years.

In order to facilitate comparison of the results derived from the different sets of observations, I give in the following table a list of periods whose length is greater than 10 years, together with the date of the first maximum after 1800:—

i. Milan Rainfall—13 (1801.0), 16 (1812.5), 30 (1818.0).
ii. Padua Rainfall—13 (1810.0), 20 (1810.0), 25 (1801.2), 35 (1804.8).
iii. London Rainfall—12 (1806.5), 35 (1809.7).
iv. Edinburgh Rainfall—13 (1800.4), 17 (1810.3), 22 (1812.1).
v. Edinburgh Pressure—14½ (1810.9), 22 (1806.5), 25 (1811.1).
vi. Paris Pressure—14½ (1807.5), 22 (1807.0), 35 (1832.8).
vii. Edinburgh Temperature—11 (1801.0), 13 (1805.3), 17 (1812.1), 23 (1803.3).
viii. Stockholm Temperature—15 (1804.0), 25 (1810.0), 35 (1830.6).
ix. London Temperature—15 (1810.0), 17½ (1811.5), 23 (1803.2).
x. Berlin Temperature—14 (1807.0), 15 (1809.6), 35 (1831.8).
xi. Paris Temperature—15 (1806.5), 30 (1800.7), 35 (1811.7).
xii. Vienna Temperature—14 (1808.3).

[5] Root, C. J., *Monthly Weather Review*, January, 1921.

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Secondary analysis by Schuster's method suggests that the 20-year period in Padua rainfall is more nearly 20.8 years, and that the 11-year and 23-year periods in Edinburgh temperature are approximately 11.4 years and 22.7 years, respectively.

Looking first at the rainfall records, we note that no one period is common to all four records, but a period of 13 years is common to three records, Milan, Padua and Edinburgh, with a reasonably close agreement of phase at the first and last of these three stations.

Pressures at Edinburgh and Paris have in common two periods of 14½ years and 22 years. In the case of the longer one the agreement of phase is good, but in the other there is a difference of phase of about a quarter of the period.

The temperature records show curious divergences from one another. Only the Edinburgh temperatures indicate a period of 11 years, which from its occurrence in the sun might be expected to show in terrestrial phenomena. The investigation of the history of this period by Schuster's method indicated a length of 11.4 years as the most likely value, and the investigation of the 23-year period in the same way indicated its length to be about 22.7 years. The amplitudes of these two periods were found to be 0.55°F. and 0.50°F. respectively.

None of the other temperature records shows a period of 11 years, but in London temperature the most striking period found in the whole range from one to 35 years was that of 23 years, which had almost accurately the same phase at London and Edinburgh. The amplitude of the 23-year period in London temperature was estimated at about 0.7°F.

A graph of two-year means of temperature at Edinburgh suggests a period of 45 or 46 years, which may be double the 22.7-year period already mentioned. There is also evidence in the periodogram of a peak about 94 months, which again is approximately one-third of 23 years.

Of the remaining periods in the temperature records, the occurrence of a 15-year period at Stockholm, London, Berlin and Paris is noteworthy, though the differences of phase are considerable. The 35-year period, famous in association with the name of Brückner, is found in temperatures at Stockholm, Berlin and Paris, the phases at the first two being in close agreement with one another and with the phase in Paris pressure.

The amplitudes of most of the temperature periods mentioned above are about half a degree Fahrenheit. On the whole, it was a little surprising to find any agreement whatsoever in the longer periods, seeing that the main features of the graphs of five yearly means of temperature were not of a periodic nature, or at least not periodic in the time scale covered by my range of periods.

4. Rainfall, Pressure and Temperature at Edinburgh.

It will be noted that Edinburgh is the only station for which observations of rainfall, pressure and temperature have been found available. It is of interest to see how the periods found in these compare with one another. The 11-year period, as already pointed out, occurs only in temperature. A 13-year period occurs in rainfall and temperature, with a difference of phase suggesting that maxi-

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mum rainfall occurs with minimum temperature. The 17-year period which occurs in rainfall and temperature, however, suggests, by the approximate equality of phase, that maxima of rainfall and temperature go together. The 23-year period is probably well determined as to length and phase in the temperature records, and it is possible that the 22-year period apparently shown by rainfall and pressure is the same period, badly determined through insufficiency of the total length covered by the available records.

A similar comparison of the periods found in rainfall and temperature for London shows no period common to both, though it is possibly significant that the period of 17½ years shown by the temperature is half the length of the 35-year period shown by rainfall.

Again, Paris pressure and temperature show one period in common, that of 35 years; but the maximum of the pressure variation occurs 14 years earlier than the maximum of the temperature variation.

5. The 17-Year Period in Edinburgh Temperature.

The Edinburgh temperature periodogram shows a fairly strongly marked peak at 17 years, the corresponding amplitude being 0.3°F. In the evaluation of this amplitude, the annual mean temperatures were arranged in rows of 17, and the columns added. The resulting totals showed a pronounced minimum in the second year. We should thus expect to find a cold year in 1765, and at intervals of 17 years after that. When the actual records are examined, it is found that a cold year occurred in 1782, 1799 and 1816, but not in any of the other years indicated. It is thus possible that the 17-year period has no physical reality, but simply arises from the occurrence of three cold years at two successive intervals of 17 years.

6. The Sunspot Numbers, 1764.

The period of 11.4 years found in Edinburgh temperatures, together with the period of about 23 years in both London and Edinburgh temperatures, suggest a connection with sunspots, which show a cycle of 11 years approximately. It was suggested many years ago that alternate sunspot cycles are of unequal strength, so that sunspots should show a period of double the length of the ordinary sunspot cycle. Further, the reversal of the sunspot polarity in alternate cycles suggested that there is an underlying physical cause whose period is double the ordinary sunspot period.

In order to obtain a reasonable comparison between sunspots and the temperature records, the sunspot numbers from 1764 onwards were analysed harmonically. The period was estimated to have a length of 11.5 years in sunspot numbers as against 11.4 years in Edinburgh temperatures.

In Edinburgh temperatures the 11-year period occurs with a phase angle of 115°, while in sunspots the corresponding phase angle is 223.° Thus maximum temperature due to this periodicity should occur when the sunspot numbers are increasing most rapidly. For the same interval, the 23-year period appears in Edinburgh and London temperatures with a phase angle of 247°, and in the sunspot numbers with a phase angle of 164°. Thus the maximum tempera-

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ture effect of the 23-year wave should occur when sunspots are decreasing most rapidly. The two waves, 11-year and 23-year, regarded for the moment as due to sunspots, thus appear to act in opposite senses in producing an effect on temperature.

It may be remarked that in sunspots the amplitude of the 23-year period is only about one-fifth of that of the 11-year period, while in Edinburgh temperatures the amplitudes of these two periods are 0.50°F. and 0.55°F. respectively.

Taking all these points into consideration, it was felt that the connection between sunspots and Edinburgh temperatures was not at all clearly established, in spite of the closeness of the two estimates of length of periods, 11.4 years in Edinburgh temperatures and 11.5 years in sunspot numbers. It was suggested by the harmonic analysis that maximum temperature should occur some two or three years before the maximum of sunspots. With a view to investigating this point a little further, the annual means of Edinburgh temperature, and the annual sunspot numbers, were plotted graphically.

In the diagram it was found that the temperature showed an irregular arrangement of peaks, some of which *did* occur two or three years before maxima of sunspots. For example, mean temperature was high, relative to the years immediately preceding or following, in 1846, 1857 and 1868, just before the sunspot maxima in 1848, 1860 and 1870. But other maxima of temperature occurred at different epochs of the sunspot cycle. A case of such occurrence was at the sunspot minimum of 1834, when the temperature was very high, and during the rise of the sunspot numbers to their next maximum in 1838, the annual mean temperature fell through a range of 4°F.

Again very low temperatures were recorded in 1816, 1838 and 1860, all three years of sunspot maxima. But 22 years after the last of these dates, in 1882, was recorded the lowest annual mean temperature which occurred during the whole interval which was considered in the present investigation. This, however, was a year of minimum sunspots.

It thus appears that although harmonic analysis appears to suggest that a relationship exists between sunspots and temperature at Edinburgh the variations of temperature are so complex, that no obvious relationship can be discovered between temperature in individual years and the phase of the sunspot variation.

There is little doubt that the difficulty is due partly to the multiplicity of periods which occur in these records and partly to the impossibility of applying strict mathematical analysis to the sunspot cycle, which changes in length and in amplitude, with no apparent law of variation.

7. Periods Shorter than 10 Years.

i. *Rainfall.*—A comparison of the periodograms for Milan and Padua rainfalls shows that they have peaks in common at $12\frac{2}{3}$, $14\frac{2}{3}$, 18 or $18\frac{1}{2}$, 23, 26 or $26\frac{1}{2}$, 31 or 32 and 54 or 56 months, with good agreement of phase, the differences of phase being between 10° and 24°, and have peaks in common at $13\frac{1}{3}$, $20\frac{2}{3}$, 49 and 72 months, with rather bigger differences of phase, varying from 40°

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to 75°. The extent to which these periodograms agree is surprising in view of the strikingly different curves of the 5-yearly totals of rainfall referred to earlier.

Of the periodicities mentioned in the last paragraph only two are found in the periodogram of London rainfall, those at $13\frac{1}{3}$ and $14\frac{2}{3}$ months, and only five are found in the periodogram of Edinburgh rainfall, those at $14\frac{2}{3}$, 31 or 32, 49, 72 and 90 months.

There is a certain general resemblance between the periodograms for London and Edinburgh rainfalls, but the greatest amplitude in the London diagram is one of 0.17 inches per month found for the $13\frac{1}{3}$ month period, which is apparently absent from Edinburgh rainfall.

There are peaks in certain of the diagrams which are possibly associated, *e.g.*, Milan rainfall shows periods of $15\frac{1}{3}$ months and 23 months, which are sub-multiples of 46 months, though no period of 46 months is evident, and it shows periods of $20\frac{2}{3}$ months and 31 months, which are sub-multiples of 62 months, though again no period of 62 months is evident.

ii. *Pressure.*—A comparison of the periodograms of pressure at Edinburgh and Paris indicates that they have in common, periods of 13, $14\frac{2}{3}$, $15\frac{1}{3}$, 16, $18\frac{1}{2}$, 29 and 35 months, all except the $18\frac{1}{2}$ month period showing close agreement in the incidence of the phase of maximum. Each of the records shows in addition certain peaks not found in the other.

Edinburgh pressure has periods in common with Edinburgh rainfall, of lengths $14\frac{2}{3}$, 19, 29, 60 and 72 months, with phases approximately reversed, corresponding to the occurrence of maximum rainfall at minimum pressure. The similar behaviour of the 13-year period in these records has already been commented upon.

The period of greatest amplitude in Edinburgh pressure is of length 31 months, and in Paris pressure that of 29 months, both having amplitudes of about $\frac{1}{2}$ mm.

iii. *Temperature.*—When the six periodograms of temperature for Edinburgh, Stockholm, London, Berlin, Paris and Vienna are compared, certain resemblances strike the eye at once. For example, the first five of these records all show a marked peak at 13 months. They all show periods round about $14\frac{2}{3}$ months, $19\frac{1}{2}$ or $19\frac{2}{3}$ months, 25 or 26 months, while London, Berlin and Paris show a marked period of 37 months. The diagrams are so complex that it is impossible to describe them in detail, and the reader who is interested in the subject must be referred to the original diagrams in the paper in the *Philosophical Transactions*.

The point which stood out as remarkable was the close agreement of the phase of the periods which were common to a number of the temperature periodograms. This will be made clear by the table below. In this table the first column gives the length of the periods which are common to three or more of the six temperature records. The next six columns give a comparison of the phases of these periods in the six records. The figures which are given in the table are the differences between the recorded phases (in degrees) and the means of all those places at which the individual periods were shown. When the phase given in a compartment of the table is in brackets, it is to be understood that in that particular

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record the period referred to does not occur at an actual peak in the periodogram, though it shows an appreciable amplitude.

TABLE I.—Comparison of Phases of Periods from 13 to 92 Months in Temperature Records of Various Stations.[5A]

Period in months.	Edinburgh	Stockholm.	London.	Berlin.	Paris.	Vienna.
13	26	−51	7	− 3	− 11	31
14⅔	− 8	−15	− 8	−16	2	36
15⅓	—	−24	−31	31	24	(211)
15⅔	(1)	(−35)	1	− 1	(2)	1
19⅓	−14	37	11	(22)	−11	−23
19½	−30	—	− 5	—	−30	27
25	5	(−11)	− 5	(−13)	(6)	—
26	(1)	—	5	2	(−10)	− 6
29	8	−14	16	−19	(34)	11
37	(−25)	—	− 4	− 8	0	11
42	13	5	22	−18	25	−46
60	−11	(24)	14	− 1	− 1	− 1
92	(4)	(22)	(42)	−21	26	− 4

(The period near 60 months is probably a little longer than 60 months, but shorter than 61 months.)

In no single case is the divergence of phase from the mean great, while in some cases the agreement is extraordinarily close.

Of the 13 periods shown in the table, those which are present in the rainfall and pressure records are shown below.

Milan Rainfall—14⅔, 15⅓ months.
Padua Rainfall—14⅔, 19½, 26 months.
London Rainfall—14⅔, 16⅔, 29, 92 months.
Edinburgh Rainfall—14⅔, 19½, 25, 29, 60 months.
Edinburgh Pressure—13, 14⅔, 15⅓, 42, 60 months.
Paris Pressure—13, 14⅔, 15⅓, 26, 29, 92 months.

8. Summary of the Results of the Present Investigation.

In endeavouring to obtain a clear idea of the results derived from the present investigation we should first of all bear in mind the nature of the material with which the investigation is concerned. It has been stated that when 5-year totals of rainfall, and 5-year means of temperature and pressure, were represented graphically, the resulting curves were characterised by large surges extending over intervals of as much as half a century, and showed little or no indications of periodicity in the ordinary scientific sense of that ill-used word. The nature of these curves indicates clearly that the main variations of rainfall, pressure and temperature cannot be represented by the superposition of a number of waves of periods less than 30 years.

The results, in so far as periods longer than 10 years are concerned, while they indicate that certain periods are common to two or more of the twelve records, do not give a close correspondence except perhaps in the case of the 15-year period occurring

[5A] Table I. should have been headed by a period of 12⅓ months, whose phases measured from mid-January 1764 are 65, 75, 67, 61, 70 and 305 degrees respectively.

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in temperatures at Stockholm, London, Berlin and Paris. In view of this the writer was surprised, on coming to the shorter periods, to find the striking correspondence of phase which has been dealt with above.

If now we consider any one of the twelve records, whether of rainfall, pressure, or temperature, we find that the number of periods indicated by peaks in the periodogram is large in general with no very outstanding one. Take for example London temperature. The following table gives a list of amplitudes greater than 0.3°F. :—

Period.	Amplitude.	Period.	Amplitude.
23 years ...	... 0.70°F.	37 months	... 0.45°F.
17½ ,, ...	... 0.51	26 ,,	... 0.49
15 ,, ...	... 0.39	25 ,,	... 0.47
98 months	... 0.41	21⅓ ,,	... 0.31
88 ,,	... 0.30	19⅓ or 19½ months	0.31
64 ,,	... 0.36	14½ or 14⅔ ,,	0.41
60 ,,	... 0.38	13 months	... 0.56
42 ,,	... 0.41	12⅓ ,,	... 1.23

We cannot establish with absolute certainty either the length or the phase of these periods, partly because in places they are banded together, and partly because they are obviously overlaid by casual or non-periodic variations.

It is therefore the considered opinion of the present writer that such periodograms are of no value for forecasting weather. This agrees with the opinion expressed in 1917 at the conclusion of an investigation of the periods in Greenwich temperatures.[6] In that investigation it was shown that the standard deviation of the monthly mean temperatures was 2.8°F., and it was shown that if the temperatures were corrected for all possible periods longer than one year, the standard deviation could only be reduced to 2.44°F.

If we accept as real all the periods given in the table above for London temperature, the sum of the square of the amplitude is 4.2. Correcting for all these periods would reduce the $(\text{s.d.})^2$ by 2.1, which is equivalent to reducing the standard deviation by about one-ninth.

Thus the main portion of the variability of temperature cannot be accounted for as due to periodic variations. The same is true of all the other series of observations of temperature, pressure and rainfall investigated.

In so far as London temperature is considered, the diagram in Fig. 1 helps us to appreciate the complexity of the problems with which we are here dealing. This diagram was prepared some ten years ago in the course of an earlier investigation of Greenwich temperatures. It shows the deviations from the means of the monthly mean temperatures at Greenwich, each month being represented separately. The scale of the variations will be seen from the fact that the distance between successive dotted lines showing mean values for the separate months represents 10°F. It appears to need a very courageous, or a very reckless person, to claim to forecast a monthly mean temperature in advance.

The diagram is included in the present paper because it is

[6] *Q.J.R. Meteor. Soc.*, **45**, 1919, pp. 323 *et seq.*

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customary for enthusiasts in this class of work to claim that certain periods are solely winter, or solely summer periods. It is seen that no month shows more signs of order in the diagram than any other.

A point arises in connection with the varying effect of a periodicity at different times of the year. If we measure time with the year as unit, a period of length $1/p$ years is represented by $A\cos(2\pi pt-\alpha)$. If now such a periodicity were supposed to show an annual variation of amplitude, a first approximation to the amplitude would be $a+b\cos(2\pi t-\beta)$. The complicated periodicity would then be represented by

$$\{a+b\cos(2\pi t-\beta)\}\cos(2\pi pt-\alpha)$$

or by

$$a\cos(2\pi pt-\alpha)+\tfrac{1}{2}b\cos\{2\pi(1+p)t-\alpha-\beta\}+\tfrac{1}{2}b\cos\{2\pi(1-p)t-\alpha+\beta\}.$$

In other words, the periodicity with varying amplitude would be indistinguishable from the joint effect of three separate periods of $1/p$ year, $1/(1+p)$ years and $1/(1-p)$ years.

Now p, $1+p$ and $1-p$ are proportional to the frequencies of the periods. The period of relative frequency $1+p$ is less than one year in length and therefore not represented in my diagrams, but the period of relative frequency $1-p$ would be shown. Actually the horizontal scale of my periodograms was a scale of frequency and therefore it was easy to find whether corresponding to any period of frequency p there was another frequency $1-p$. To carry out the search, all that was required was a pair of dividers with which to search for frequencies equally distant from two years, which has a relative frequency of $\frac{1}{2}$. I was unable to test the existence of the periods of frequency $1+p$, which are shorter than 12 months, as I had definitely abandoned the idea of searching for periods shorter than one year, on account of the impossibility of forming a sufficiently close network of trial periods. A number of periods which appeared roughly to correspond were found and are shown below:—

	Period of frequency p.	Period of frequency $1-p$.
Series i.	54 months	$15\frac{3}{7}$ months (peak between $15\frac{1}{3}$ and $15\frac{1}{2}$).
	10 years	$13\frac{1}{3}$ months.
Series vi.	14 years	12.92 months (peak at 13 months).
	56 months	15.27 months (peak at $15\frac{1}{3}$).
	49 months	15.89 months (peak at 16 months).
Series vii.	36 months	18 months.
	(11.4 years)	13.15 months (peak at 13 months).
Series viii.	66 months	$14\frac{2}{3}$ months.
	56 months	15.27 months (peak at $15\frac{1}{3}$).
Series ix.	56 months	15.27 months (peak at $15\frac{1}{3}$).
	42 months	16.8 months (peak at $16\frac{2}{3}$).
	37 months	17.76 months (peak at $17\frac{2}{3}$).
Series x.	14 years	12.92 months (peak at 13).
	66 months	$14\frac{2}{3}$ months.
	42 months	16.8 months (peak at $16\frac{2}{3}$).
Series xi.	6 years	14.4 months (peak at $14\frac{1}{2}$).
Series xii.	42 months	16.8 months (peak at $16\frac{2}{3}$).
	36 months	18 months.

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No other periods gave even an approximate correspondence.

A rough check was carried out for the 42 months period in London temperatures with mean summer and winter temperatures for 1841-1919 which happened to be available. There was no appreciable difference in their amplitudes and their phases only differed by a fraction of a year.

9. PERIODICITIES WHICH ARE FINALLY PUT FORWARD AS SIGNIFICANT.

1A. 12⅓ months. (All the series investigated except Edinburgh rainfall.)
1. 12⅔ months. (Milan and Edinburgh rainfall.)
2. 13 months. (Edinburgh and Paris pressure; temperature at Edinburgh, Stockholm, London, Berlin and Paris.)
3. 13⅓ months. (Padua and London rainfall; possibly Vienna temperature.)
4. 14⅔ months. (Rainfall at Milan, Padua, London and Edinburgh; the true period for London is possibly slightly longer than 14⅔ months and for Edinburgh slightly shorter than 14⅔ months; also in pressure at Edinburgh and Paris; and in temperature at Edinburgh, Stockholm, London, Berlin and Paris; Vienna temperature appears instead to have a period of 14½ months.)
5. 15⅓ months. (Milan rainfall; pressure at Edinburgh and Paris; temperature at Stockholm, London, Berlin and Paris.)
6. 16 months. (Edinburgh and Paris pressure.)
7. 16⅔ months. (Rainfall at Edinburgh and London; temperature London, Berlin and Vienna.)
8. 18 months. (Padua rainfall; Edinburgh temperature.)
9. 18½-18⅔ months. (Milan rainfall; Padua rainfall; Edinburgh and Paris pressure; Stockholm and Paris temperature.)
10. 19 months. (London rainfall; Edinburgh pressure; Berlin temperature.)
11. 19⅓ or 19½ months. (Padua and Edinburgh rainfall; Edinburgh, Stockholm, London, Paris (?) and Vienna temperatures.)
12. 20⅔ months. (Milan and Padua rainfall; Edinburgh pressure.)
13. 21 months. (Edinburgh rainfall; Paris pressure; Vienna temperature.)
14. 21⅓ months. (Temperature at Edinburgh, Stockholm, London and Berlin.)
15. 23 months. (Milan, Padua and London (?) rainfall; Edinburgh and Paris pressure; London and Paris temperatures, possibly present with small amplitudes in Edinburgh and Vienna temperatures.)
16. 24 months. (Temperature at Stockholm and Paris; possibly London rainfall.)
17. 25 months. (Edinburgh rainfall, pressure and temperature; London temperature.)
18. 26 months. (Padua rainfall; Paris pressure; London, Berlin and Vienna temperature; possibly the period of 26½ months in Milan rainfall.)

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19. 29 months. (Minor peak in Milan and Padua rainfall; London and Edinburgh rainfall (note that Edinburgh rainfall appears to show an independent period of 28 months); pressure at Edinburgh and Paris; temperature at Stockholm, London, Berlin and Vienna.)
20. 31 months. (Milan rainfall; Edinburgh rainfall, a period which may be slightly longer; Edinburgh pressure; while Padua rainfall shows a period of 32 months; and London rainfall shows 31 months as a possible small periodicity.)
21. 35 months. (Padua and London rainfall; Paris pressure with small amplitude; Stockholm temperature.)
22. 37 months. (Temperature at London, Berlin, Paris and Vienna; the period for Vienna may possibly be slightly less than 37 months.)
23. 42 months. (Edinburgh pressure; temperatures at Edinburgh, Stockholm, London, Berlin, Paris and Vienna.)
24. 48 months. (London rainfall; Stockholm, Berlin and Paris temperatures.)
25. 49 months. (Milan rainfall; rather small amplitude in Padua rainfall; Edinburgh rainfall; Paris pressure; Vienna temperature.)
26. 52 months. (Vienna temperature.)
27. 56 months. (Padua rainfall; Paris pressure; Stockholm temperature.)
28. 60 months. (Edinburgh rainfall; relatively slight in London rainfall; Edinburgh pressure; Edinburgh, London, Berlin, Vienna temperatures; Paris temperature indicates a period nearer to 62 months.)
29. 64 months. (Padua rainfall; London temperature.)
30. 66 months. (Stockholm, Berlin and Vienna temperature.)
31. 72 months. (Milan, Padua and Edinburgh rainfall; Edinburgh temperature; also relatively small amplitude in Paris temperature.)
32. 74 months. (London rainfall; Edinburgh pressure; Berlin temperature.)
33. 90 months. (Relatively small amplitude in Milan rainfall; Padua and Edinburgh rainfall; Vienna temperature; and an 88-month period in London temperature may be the same.)
34. 92 months. (London rainfall; Paris pressure; Edinburgh temperature gives high amplitudes for 90, 92 and 94 months.)
35. 98 months. (100 months in Padua and Edinburgh rainfall; London rainfall and temperature.)
36. 104 months. (Milan and London rainfall; 106 in Edinburgh pressure; Stockholm temperature; also in Paris temperature, but with relatively small amplitude.)
37. 114 months. (London and Edinburgh rainfall; in Paris pressure as 116 months.)
38. 11.4 years. (Edinburgh temperature.)
39. 13 years. (Milan, Padua and Edinburgh rainfall; rather weak in Edinburgh temperature.)

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40. 14 years. (Rather weak in Edinburgh and Paris pressures; Berlin and Vienna temperatures.)
41. 15 years. (Stockholm, London and Paris temperatures.)
42. 17 years. (Edinburgh rainfall; 17½ years in London temperature, and possibly it is the same period which gives an apparent 16-year period in Milan rainfall.)
43. 22-23 years. (Edinburgh rainfall; Paris pressure; Edinburgh and London temperatures.)
44. 35 years. (London rainfall; Paris pressure; Stockholm and Berlin temperatures.)

Of the 44 periods suggested above, some may appear extremely near to each other to be classed as independent periods. For example, periods of 48 and 49 months are found in different records. But the amplitudes for both 48 and 49 months were evaluated in all cases and so the peak in the diagram could be clearly assigned. There is a group of periods from 88 to 92 months which may be associated in some way.

A comparison of this table with the results of other investigators is given later in this paper.

Although it is not considered that the results derived in the course of this investigation are ever likely to be of practical use to the forecaster, it is considered that from the point of view of dynamical meteorology they are of considerable importance. For a number of periodicities have been discovered which are strong enough to persist through 100 years of observations, and to persist with the same phase. This brings us to the most important limitation of the present investigation. It is not possible to carry out in a straightforward manner any investigation of periodicities which does not assume that the phase of the periods remains unaltered; and this assumption underlies all the work here described. It is possible that a number of periodicities not discovered may have been in existence for a part of the time, or may have persisted through the whole interval, with abrupt changes of phase from time to time. But whether this is so or not, it is maintained that the periods which appear to persist through a century with constant phase, and which appear in records at widely separated stations, must be of physical importance. It is not proposed to discuss the reality of these periods on the basis of the theory of probability, as the writer is of opinion that their appearance at widely separated stations, with approximately the same phase, is in itself sufficient to invest these periods with physical significance.

These periods would appear to be the periods of oscillation of the whole or part of the earth's atmosphere, and it is suggested that they may be periods of oscillation of the general circulation of the earth's atmosphere.

10. Comparison with the Results of other Investigators.

Although in the earlier stages of the computations the twelve series of observations discussed above were treated together the amplitudes and phases were evaluated separately for each series. Each periodogram was checked and graphed separately, and no attempt was made to compare the diagrams with one another until they had all been completed and drawn. It was

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considered that the programme arranged for the investigation was sufficiently thorough to detect all periodicities greater than one year in length, and it was desired to avoid the temptation to find periods where it was felt they should occur. This plan appeared to be likely to avoid any personal bias. Further, the earlier work was completed and published, and the present paper written down to the present paragraph before any attempt was made to compare the results derived with those of earlier workers.

A brief summary of the results derived by earlier workers is given below, with some comparison with the results of the present paper. This comparison is not exhaustive, as the literature of the subject is exceedingly voluminous and for the most part exceedingly diffuse. A great many writers put forward claims to the discovery of certain periodicities when only a few amplitudes have been evaluated; and in general the literature of this branch of meteorology has suffered from the lack of coordination.

The references given below are classed in accordance with the numbers 1 to 44 assigned to the periods in the table above. It is seen that a number of the periods given in the table above are not represented in the work of the writers to whose papers I have been able to refer.

3. 13⅓ months. Göschl, F., *Met. Zeit.*, **33**, 1916, p. 230. Position of high pressures moving across Europe.

11. 19⅓ or 19½ months. Turner, H. H., *London, Q.J.R. Meteor. Soc.*, July, 1911. Greenwich Rainfall 597 days, Padua Rainfall 592 days.
Young, M., *London, Proc. R. Soc. Med.* XIII., 1920, pp. 207-234. Gives period of 86 weeks in incidence of whooping cough

15. 23 months. Wallen, A., *Met. Zeit.*, **31**, 1914, p. 209. Rainfall at Thorshavn.

16. 24 months. Woeikof, A., *Met. Zeit.*, **23**, 1906, p. 43. Stockholm Temperatures; marked periodicity of 2 years in winter.
Wallen, A. (*vide* 15), Temperatures Bergen and Göteborg.
Young, M. (*vide* 11), Incidence of whooping cough, 2 years.

17. 25 months. Brooks, C. E. P., *London, Met. Mag.*, 1920, p. 205. Rainfall at Bathurst.
Wallen, A. (*vide* 15), Rainfall at Bergen, Upsala and Moscow.

18. 26 months. Wallen, A. (*vide* 15), Rainfall Tromso, Petrograd, Temperature Thorshavn, Tromso, Stockholm, Moscow.
Beveridge, W. H., *London, Jour. R. Stat. Soc.*, **85**, 1922, pp. 412-478. Wheat prices.
Arctowski, *Washington, Proc. 2nd Pan. Amer. Sci. Congress*, **2**, p. 172. The pleisnian cycle of climatic fluctuation, 2.2 years, in temperatures in various parts of the world.

19. 29 months. Baxendell, J., *London, Q.J.R. Met. Soc.*, **51**, 1925, p. 371, Rainfall Southport and Bolton.
Baur, F., *Bayern, Deutsches Met. Jahrb.*, 1922, Pressure and Temperature at various central European stations.
Beveridge, W. H. (*vide* 18). Wheat prices.

21. 35 months. Baxendell, J. (*vide* 19), Rainfall of Southport and Bolton; a period given as about 34 months.
Shaw, W. N., *London, Proc. R. Soc.*, A, **78**, 1906, p. 69, period of 2.8± years in wheat yield Eastern England.

22. 37 months. Baxendell, J. (*vide* 19), London Temperatures and Lancashire Rainfall.
Radcliffe Observations LII. Rainfall at Oxford.
Brooks, C. E. P., *London, Met. Mag.*, 1920, p. 205. Rainfall at Bathurst shows period of 38 months.
Jenkin, A. P., *London, Q.J.R. Met. Soc.*, **39**, 1913, p. 29. Rainfall at 25 stations showing periods above 3 years, averaging 3.155 years.
Braak, C., *Batavia K. Magnet. en Meteor. Observ. Verh.*, **5**, 1919. Pressure and Rainfall of Batavia show period of 3 years.

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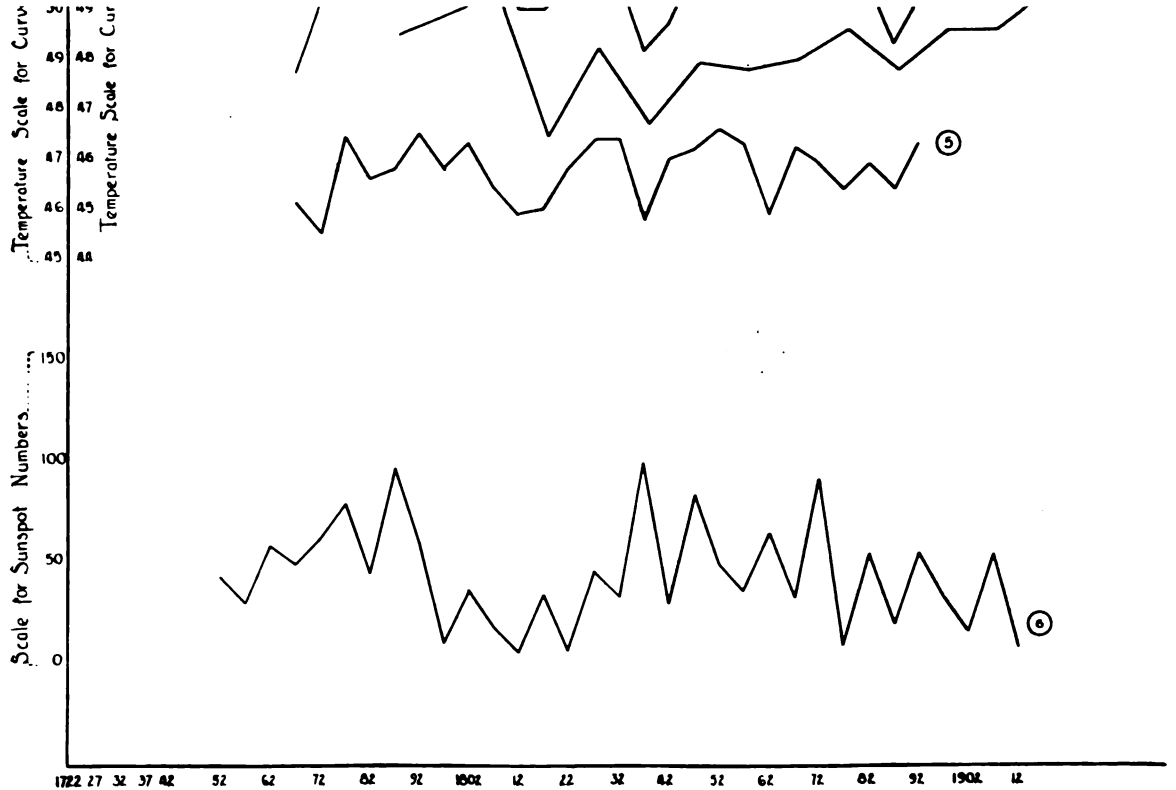

FIG. 2.

(1) Padua Rainfall, 5 yearly totals; (2) Paris Pressure, 5 yearly means; (3) London Temperature, 5 yearly means; (4) Temperature, certain American stations, 10 yearly means; (5) Edinburgh Temperature, 5 yearly means; (6) Sunspot numbers, 5 yearly means.

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23. 42 months. Elton, *Brit. Journ. Exp. Biol.*, **3**, October 1924. Period of 3½ years in fluctuations of numbers of certain animals.
Beveridge, W. H. (*vide* 18), wheat prices, 3.415 years.
26. 52 months. Baxendell, J. (*vide* 19). Rainfall at Southport.
Beveridge, W. H. (*vide* 18). Wheat prices.
Meinardus, *Berlin, Ann. Hydrog.*, **34**, 1906, pp. 148, 227, 278. Period of over 4½ years in Arctic ice.
28. 60 or 61 months. Baxendell, J. (*vide* 19). London temperatures; wind direction at Southport and Greenwich.
30. 66 months. Brooks, C. E. P., *London, Met. Mag.*, 1921, p. 113. Temperature Northern and Western Europe; period of 5.6 years.
Beveridge, W. H. (*vide* 18). Wheat prices.
31. 72 months. Beveridge, W. H. (*vide* 18). Wheat prices; period 5.96 years.
Beveridge, W. H. (manuscript). Swedish birthrate; 6 years.
Brook, C. (*vide* 22). Pressure at Port Darwin; 6 years.
33. 90 months. Douglass, "Climatic Cycles and Tree Growth," *Washington, Carnegie Inst.* Period of 7.3 years in trees, Arizona.
Beveridge, W. H. (*vide* 18). Wheat prices; period 89 months.
34. 92 months. Woeikof, A., *Met. Zeit.*, **33**, 1906, p. 430. Period 7.9 years in winter temperatures, Stockholm.
35. 98 months. Maurer, J., *Met. Zeit.*, **35**, 1918, p. 95; 8 year period in high pressure over Alps.
Moore, H. L., "Economic Cycles;" 8 year period in rainfall, Ohio Valley.
Bigelow and Petterson find 8 year period in pressure records, Europe and America.
Beveridge, W. H. Wheat prices; 8.05 years period.
37. 114 months. Rawson, H. E., *London, Q.J.R. Met. Soc.*, **34**, p. 165. Mean position of high pressure belt of Southern Hemisphere E. and W. of S. Africa; period 9½ years.
Lockyer, W. J. S., "Australian Meteorology;" pressure, Australia; period 9½ years. Various writers have found 9½ year period in Nile Floods.
Beveridge, W. H. (*vide* 18). Wheat prices; period 9.75 years.
38. 11.4 years. Brooks, C. E. P., *London, Met. Mag.*, 1920, p. 205. 11 year period in Rainfall at Bathurst.
Brooks, C. E. P., *London Metcor. Off. Geophysical Memoirs*, No. 20. Level of Lake Victoria; 11 year period.
Beveridge, W. H. (*vide* 18). Wheat prices.
Elton (*vide* 23). "Fluctuations of Animals;" 10-11 year period.
39. 13 years. Beveridge, W. H. (*vide* 18). Wheat prices; period 12.84 years.
40. 14 years. Beveridge, W. H. Swedish birthrate; period 13½-14 years.
41. 15 years. Beveridge, W. H. (*vide* 18). Wheat prices; period 15.225 years.
42. 17 years. Beveridge, W. H. (*vide* 18). Wheat prices; period 17.4 years.
44. 35 years. Brückner, *Klimaschwankungen*; period of 35 years in (1) Ice conditions in rivers of Europe, Siberia, and Hudson, (2) Date of wine harvest in France, and (3) Frequency of cold winters in Europe.
Clough, H. W., *Astrophys. Jour.*, **22**, 1905, p. 42, finds 36 year period in Brückner's data with some added data.
Baur, F., *Bayern, Deutsch. Met. Jahrb.*, 1922; 36 year period in temperature and pressure of a number of Central European Stations.
Brooks, C. E. P., *M.W. Rev.*, 1919, p. 637; period of 36 years in rainfall of Chile.
Moore, H. L., "Economic Cycles;" period 33 years in rainfall of Ohio Valley.

In addition to the periods classified above, various writers claim to have demonstrated the existence of certain longer periods in weather. The longest of these is a period of 744 years, with its sub-multiples 372 years and 186 years, advocated by the Abbé Gabriel.[7] Next to these comes a period of 260 years, found in Tree Rings, Earthquakes and Nile Flood minima,[8] and shown by

[7] *Comptes Rendus*, **181**, No. 1, 1925, p. 22.
[8] Mohorovičic, *Met. Zeit.*, **38**, 1921, p. 373.

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Fotheringham[9] to fit the records of Chinese earthquakes. A period of 171 years, with a sub-multiple of 57 years, was ascribed to Nile Floods,[10] and in the same paper Keele claimed that periods of 57 years and 19 years occur in British rainfall. Periods of 155 years, 33.8 years and 21 years were found in tree rings.[11] The 155-year period was shown to exist in the records from 1400-1900, while the 33.8-year period was found from 1730-1910, but not earlier than 1730. A long period of 108 years, with the sub-multiple 36 years, was found in Bathurst rainfall.[12] A period of 130 years in the occurrence of severe winters was found by Köppen.[13] A period of 89 years and one of 44½ years in the winter temperature of Western Europe since A.D. 760 were found by C. Easton.[14] These periods were also advocated by Köppen.[15]

One of the most widely discussed periods in meteorology is that of 19 years, which was noted in Australia even before the existence of rainfall or pressure records in that continent. This period was detected in records of pressure in Australia and South Africa by W. J. S. Lockyer.[16] It was shown by Rawson to exist in the variation of extreme positions to north and south of the high pressure belt of the southern hemisphere, in the regions to east and west of South Africa.[17] A period of about the same length, ascribed to the 18.6 year lunar period, was discussed by F. Schuster.[18]

One of the most striking papers recently published on periodicities is that of A. Wagner on an investigation of Vienna temperatures.[19] Wagner found a period of 16 years in both summer and winter temperatures, but with opposed phases, so that the period is inappreciable in annual mean temperatures. He found that in summer-winter temperatures, it showed an amplitude of 0.735°C., and similar results were derived for 15 other Central European stations. In the differences between summer and winter temperatures at the mountain stations at Obir and Sonnblick the 16-year period has the remarkable amplitude of 2½ to 3°C.

The references given above are in no sense exhaustive. Enough has been said, however, to show that the number of periodicities which are claimed to exist is very great. The evidence adduced in favour of the majority of the longer periods is not convincing, as, from the very nature of things, instrumental observations are not available to prove to demonstration the existence of these cycles.

Returning to the table above, it is seen that most of the 44 periods of my table are well supported by the work of other investigators. The most striking periods found in my investiga-

[9] *Monthly Notices, R. Astr. S.*, **79**, p. 578.
[10] Keele, T. W., *Proc. R. Soc., N.S. Wales*, **44**, 1910, p. 25.
[11] Huntington, E., " The Climatic Cycle as illustrated in arid America; " *Carnegie Institution*, 1914.
[12] Brooks, C. E. P., *M.W. Rev.*, 1919, p. 637.
[13] *Zeit. Oesterr. Gesell. Meteor.*, **8**, 1873, pp. 241, 257, and **16**, 1881, pp. 140, 183.
[14] *Amsterdam Proc. K. Akad. Wet.*, **20**, 1919, No. 8.
[15] *Met. Zeit.*, 1918, p. 98.
[16] A Discussion of Australian Meteorology, *Publications of Solar Physics Observatory.*
[17] *Q.J.R. Meteor. Soc.*, **34**, p. 165.
[18] *Ann. Hydrog.*, **42**, 1914, p. 433, and **44**, 1916, p. 442; also *Met. Zeit.*, 1913, p. 488.
[19] *Wien, Sitzber. Akad. Wiss.* IIa., Vol. 133, 1924, pp. 169, 224.

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tions, which I cannot trace in references to the work of earlier investigators, are those of $12\frac{1}{3}$ months, 13 months, $14\frac{2}{3}$ months, $15\frac{1}{3}$ months, $20\frac{2}{3}$ or 21 months and 49 months. These all appear in my periodograms as well marked periods. In particular, the $12\frac{1}{3}$-month and 13-month periods are about the most striking of all the periods in the six temperature records. It must be admitted, however, that the shorter periods have received far less attention than longer periods from earlier workers.

11. Theories of the Physical Origin of Periodicities.

Much has been written on the possible causes of the origin of periodicities, but little of it is in any way conclusive. The only certain relationship is that of the annual variations with solar radiation. Periods of about 11 years have universally been ascribed to the effect of sunspots, and one of about $18\frac{1}{2}$ to 19 years to the effect of the moon. Petterson in a lengthy discussion "On the occurrence of lunar periods in solar activity and the climate of the earth,"[20] discusses a number of lunar periods, such as the moon's apsidal period of 8.857 years, and the mean time from one perigee to the next, 9.3 years, and considers their relation to solar and terrestrial atmospheric phenomena.

Most of the theories advanced hitherto ascribe the periodicities in atmospheric phenomena to astronomical causes. It is possible, however, that the periods, or at least the shorter ones, are natural periods of oscillation of the general circulation of the earth's atmosphere, which are perhaps set in motion by causes external to the earth itself. The question is too involved to enter upon here and further discussion of it is postponed till some future occasion.

Note added November 25th, 1926.

12. The Effect of Casual Variations on Periodogram Analysis.

It has been pointed out by numerous writers that if a series of observations consists of numbers distributed at random, harmonic analysis of these figures will lead to amplitudes which in some cases may appear to be so high as to denote real periods. For a period of length T years, the mathematical expression of the assumed harmonic variation is $C \cos 2\pi t/T + S \sin 2\pi t/T$, t representing time, measured in years. The arithmetical work consists in evaluating the values of C and S. We may suppose the system of figures distributed at random to lead to values C' and S' for these coefficients. If there is a real physical variation of period T years, represented by $C \cos 2\pi t/T + S \sin 2\pi t/T$ superposed on the random or chance distribution of figures, then the attempt to evaluate the amplitude of this period will lead to values $C+C'$ and $S+S'$ of the respective coefficients. We cannot in any individual case separate the totals $C+C'$ and $S+S'$ into their components. The amount of the casual or chance coefficients C', S', is always unknown. The amplitude R which is derived from the analysis is given by $R^2=(C+C')^2+(S+S')^2$, and the phase of maximum ϕ is given by $\tan\phi=(S+S')/(C+C')$. Thus both the amplitudes and

[20] *Ur Svenska Hydrog. Biol. Komm. Skrifter.* Häft V.

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phases of all the periods are affected by the casual variations which give rise to C' and S', and even in cases where there is a true physical period of length T years, neither the amplitude nor phase can be stated with certainty. Further, since the values of C' and S' differ even for adjacent periods, the casual variation may cause a peak in the periodogram to be displaced from the true period. Thus, even the lengths of the periods deduced from the periodogram will be uncertain.

Each of the twelve periodograms discussed above showed a large number of peaks, which may be assumed to give the likeliest real periods. But since each period is uncertain as to length, amplitude, and phase, it is not possible to use with confidence the results derived, for the purpose of drawing a graph of the conditions to be expected at any future time.

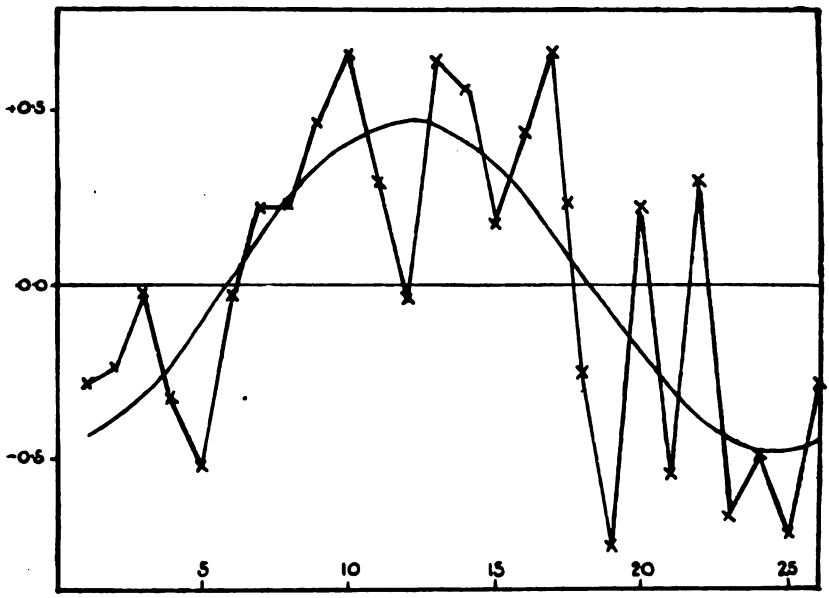

FIG. 3.—25-months trial period. Unsmoothed totals and the derived sine curve.

There is an added element of uncertainty, in that earlier investigations have shown that in Greenwich temperatures[21] certain periods appear to exist for a time and die away suddenly.

Some idea of the extent to which it is safe to apply a particular period to prediction may be gained from Figs. 3 and 4, which give the crude figures used in the evaluation of the amplitudes and phases of the periods of 25 months and 23 years respectively. The crosses in Fig. 3 represent the mean of 48 cycles of 25 months, while those in Fig. 4 represent the mean of six cycles of 23 years. It will be seen that in each case the actual figures used follow somewhat irregularly the sine-curve, but that the deviations from the sine-curve may amount to as much as the amplitude of the sine-curve itself. These deviations may in part be due to the

[21] *Vide Q.J.R. Meteor. Soc.*, XLV., pp. 323-338, 1919.

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superposed casual variations, and in part to the interference of other periods, particularly of sub-multiples of the main periods of 25 months or 23 years respectively.

13. Comparison with the Periodogram of Greenwich Temperatures, 1841-1890.

The present writer carried out an investigation[22] of periods in Greenwich temperatures (1841-1890) some years ago. It may be of interest to compare the periods which predominated in that analysis with those which predominate in the present analysis of London temperatures, and are enumerated in Section 8 above. In the earlier investigation a complete Fourier sequence was evaluated, showing all periods longer than one year. If q represents the order of the Fourier term giving the probable period, then the length of period is $600/q$ months. The table below is copied from the earlier paper, all amplitudes of 0.3°F. or greater being given, for periods between one and ten years.

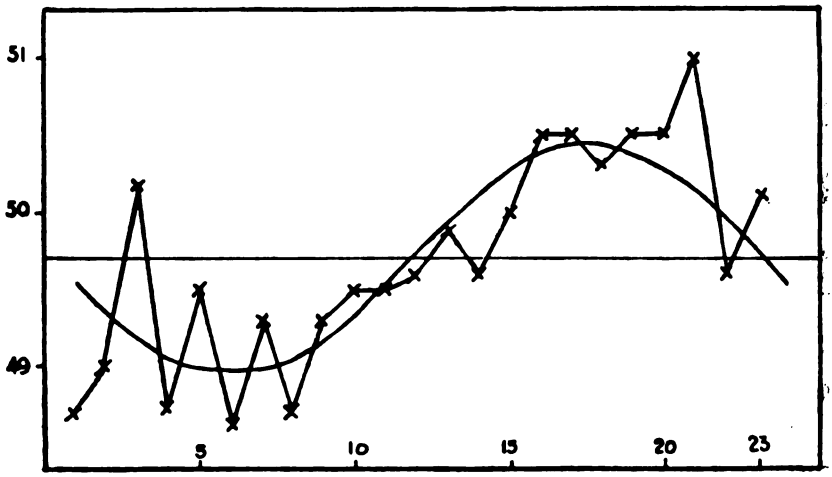

Fig. 4.—23-year trial period. Unsmoothed totals and the derived sine curve.

TABLE I.—Amplitudes of periods between 1 and 10 years in Greenwich temperatures.

q.	Period.	Amplitude.	Corresponding Period and Amplitude in Section 8.
6	100 months	0.6°F.	98 months. 0.4°F.
8	75 ,,	0.5°F.	?
10	60 ,,	0.4°F.	60 months. 0.4°F.
12.64	47.5 ,,	0.4°F.	?
16	37.5 ,,	0.3°F.	37 months. 0.45°F.
21	28.6 ,,	0.3°F.	(29 months.) 0.27°F.
23.32	27 ,,	0.6°F.	26 months. 0.5°F.
26.43	23 ,,	0.5°F.	(23 months.) 0.25°F.
30.71	19.5 ,,	0.5°F.	19⅓ or 19½ months. 0.31°F.
41	14.63 ,,	0.35°F.	14⅔ months. 0.41°F.

[22] A periodogram analysis of the Greenwich temperature records, *Q.J.R. Meteor. Soc.*, XLV., pp. 323-338, 1919.

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There is no evidence in the earlier analysis of periods of 13 months and $12\frac{1}{3}$ months, but it will be seen that periods of $14\frac{2}{3}$ months, $19\frac{1}{2}$ months, 23 months, 29 months, 37 months, 60 months, and 98 or 100 months, are common to both. The later analysis was based upon observations for 1764-1863, the earlier upon observations for 1841-1890. The interval common to both is thus 24 years. The correspondence is sufficiently close to justify the assumption that these periods are not simply the result of a chance distribution of the figures analysed.

14. The Effects of Periods Whose Lengths Approximate to a Year.

It was shown in Section 8 above that a period of length $1/p$ years, whose amplitude differed in summer and winter, might appear in the analysis as the joint effect of three periods, of length $1/p$, $1/(1-p)$, $1/(1+p)$ years respectively. In the special case where the period $1/p$ appears in summer and winter with the same amplitude but opposite phases, this period will not appear at all in the yearly means, and a straightforward analysis of the data will yield only the periods of length $1/(1-p)$ years, and $1/(1+p)$ years. If the period $1/p$ years is long, p is a small fraction, and the periods of length $1/(1-p)$ and $1/(1+p)$ years will be very near to the year in length.

Thus periods which are near the year in length are deserving of a closer scrutiny than they have received as yet, either in the present discussion or elsewhere. Their effect can be stated without recourse to any equation. For the sake of brevity we shall consider temperature variations only. A period whose length is near to one year will in some years attain its maximum phase in summer at the time when the normal annual variation attains its maximum. In such a year we may look for a summer temperature above the normal. Six months later when the annual variation attains its minimum, the other period whose length is not very different from one year will also be near its minimum, and so the resulting winter temperature will be below normal. Such a year will have a warm summer and a cold winter. In years when the period in question attains its minimum in summer, there will be a cool summer and a mild winter.

Thus an investigation of periodicities in differences of summer and winter temperatures may be expected to yield periods whose lengths are determined by the beats with the annual variation of those periods in the original data whose lengths are near one year. For example, if the original data show a period of $12\frac{1}{3}$ months, the length of the beats will be 37 years, and an investigation of summer or winter temperatures, or of the differences between them, will yield a period of 37 years. This period happens to fall near the Brückner period, and will be considered later in some detail, but it should be noted that a beat of exactly 35 years would be derived from a fundamental period of 12.28 months, or one of $11\frac{2}{3}$ months.

It has been stated earlier that no systematic investigation of periods shorter than one year was undertaken, on account of the difficulty of making the network sufficiently close to ensure that

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no important periodicity should be missed. A number of trial periods less than one year were, however, calculated incidentally in the course of the work. In particular, trial periods of $11\frac{1}{3}$, $11\frac{1}{2}$ and $11\frac{2}{3}$ months were evaluated for all the twelve series of observations. In the case of the six temperature series, the amplitudes for all three were in no case less than half a degree Fahrenheit, and the phases for the six stations showed a very close agreement. It is not for a moment suggested that this fixes the lengths of the periods accurately, but in order to see what kind of effect may be expected from beats of these periods with the annual variation, we shall for the moment assume that there are true periods of these exact lengths. The periods whose lengths are near one year are given below :—

Length of period.	Length of beat.
$11\frac{1}{3}$ months.	17 years.
$11\frac{1}{2}$,,	23 ,,
$11\frac{2}{3}$,,	35 ,,
$12\frac{1}{3}$,,	37 ,,
13 ,,	13 ,,
$14\frac{2}{3}$,,	11 ,,

Reference has been made in Section 10 to an investigation by Wagner of the differences of summer and winter temperatures at Vienna, in which a period of 16 years was the outstanding feature. This appears to correspond to the beat of the period which we provisionally assumed to be $11\frac{1}{3}$ months. In order to obtain beats of exactly 16 years, we need only correct this estimate to 11 5/17 months, or 11.3 months. In Vienna temperatures the amplitude of this period is 0.43°C. and the amplitude of the beat of 16 years in the difference of summer and winter temperatures should therefore be 0.86°C., which is sufficiently near to Wagner's estimate of 0.735°C., which is itself to some extent low on account of its having been computed from the mean temperature for three months. Further, an examination of the phases of the $11\frac{1}{3}$ and 12 months' variations at Vienna shows that 1780 should be a year of warm summer and cold winter, *i.e.*, of maximum annual variation. Wagner (*loc. cit.*) assigns the date 1779 to the corresponding maximum.

Wagner finds that his period of 16 years shows up still more strongly in the annual variation of mountain stations such as Obir and Säntis. This suggests that at mountain stations the fundamental period of 11.3 months is more pronounced than it is at lower levels.

Wagner (*loc. cit.* p. 181) gives a detailed periodogram of the differences of summer and winter temperatures at Vienna. Leaving out the shorter periods of less than ten years for the moment, we find the main peaks at 16 years, 19 years and 33 years. The first of these we have accounted for as a beat of a fundamental period of 11.3 months. The second, 19 years, may be the beat of a fundamental period of $12\frac{2}{3}$ months, or 11.4 months, presumably the latter, since there is no peak in the Vienna periodogram at $12\frac{2}{3}$ months. The period of 11.4 months may account for the large amplitude at 11.5 months mentioned above, whose phase is 257°. The maximum of the beat is attained in summer of 1778. Wagner

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assigns as the first date of maximum phase 1777, which is again in good agreement.

The period of 33 years may be the beat of a fundamental period of $12\frac{3}{8}$ months, or of 11 11/17 months. The second of these is probably the effective one, as it is close to the period of $11\frac{7}{8}$ months for which we found a large amplitude. The date of the first maximum given by the beat due to the $11\frac{7}{8}$-month period is 1791, while Wagner gives for his 33-year period the date 1793, again in reasonably close agreement.

It might equally be expected that the 16-year period in the differences of summer and winter temperatures should appear in all the other series analysed. This is confirmed by Wagner (*loc. cit.* p. 198), who found large amplitudes for this period in temperature records of Berlin, London and Stockholm.

At an early stage in the present investigation, Mr. C. E. Britton, who supervised a considerable portion of the computations, carried out a periodogram analysis of the annual variation of temperature at Edinburgh. The outstanding peaks were at six years, and round about 35 years, with a slightly lower peak at 13 years. The peak at six years would correspond to the beat of a fundamental period of 14.4 months or of 10 2/7 months, most probably the latter. The peak at 13 years should be the beat of the 13-month period. The analysis of the phases of the fundamental period shows that the maximum annual range should occur in 1765 and at intervals of 13 years from that date. Mr. Britton's analysis makes the corresponding date 1764, which may be taken as in sufficiently good agreement. With regard to the 35-year period, whose length cannot be regarded as very definitely fixed, we have to consider the beats of one or both of the two periods of $11\frac{7}{8}$ and $12\frac{1}{8}$ months. The former would give the maximum annual range in 1779, and at intervals of 35 years from that date, while the latter give the maximum annual range in 1776 and at intervals of 37 years from that date. Mr. Britton's analysis gives 1780 as the corresponding date of the first maximum range (corresponding closely to the date of maximum 1779 of the beat of the period of $11\frac{7}{8}$ months). Thus all the main features of the periodogram of annual range can be explained as beats of the fundamental periods of length near one year.

The amplitude of the 16-year period in the annual range at Edinburgh was considerable, though there was no peak at 16 years in the periodogram.

It should be noted that the periods near one year in length do not appear in the annual mean temperatures, but appear in the temperatures of any season, showing more markedly in summer and winter than in spring and autumn, on account of the extreme values to which they then give rise. In short, they affect the annual range without affecting the annual mean.

This is the probable physical explanation of the periods which are frequently said to show up more strongly in one season than in another, as well as of such periods as the one of 16 years discovered by Wagner in annual range of Vienna temperatures. It is now suggested that these periods are beats with the annual variation of periods near the year in length. These beats may

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also appear in the growth of trees[23] (since their growth is likely to be accelerated in a warm summer more than it is retarded by the cold winter following it), in the height of rivers in the wet season, and in estimates of ice in winter. And in general, any phenomena restricted to a season of the year may show similar beats, superposed possibly upon periods occurring in the annual temperature or rainfall records.

The analysis of the beats with the annual variation affords a useful method of determining accurately the length of periods near a year in length.

15. The Brückner Cycle.

We have seen that the periods of $11\frac{2}{3}$ and $12\frac{1}{3}$ months should give beats of 35 and 37 years respectively with the annual variation. This at once raises the question as to whether the so-called Brückner cycle may not be due to the action of these two beats, it being recognised that neither length is known with absolute accuracy.

For the purpose of the present argument we shall assume the two periods $11\frac{2}{3}$ months and $12\frac{1}{3}$ months to have phase angles of 34° and 68° respectively, these being the mean values of the phases in the six temperature records, the mean phase of the annual variation being 184°. The 35-year cycle should then give maximum annual range in 1779 or 1780 and at intervals of 35 years later, while the 37-year cycle should give maximum annual range in 1776, and at intervals of 37 years later. The years so determined should have warm summers and cold winters, while the intermediate years should have cool summers and mild winters. The two cycles so assigned should reinforce one another in 1850, when both give maximum annual range.

Brückner's derivation of his period,[24] in so far as it concerned temperature, was based on annual mean temperatures. The Brückner cycle cannot therefore be regarded as due to beats of the nature considered in Section 14 above. Further, we have found a period of 35 years in several of the temperature records, giving maximum annual mean temperature in 1830 or 1831, at Stockholm and Berlin, and in 1811 at Paris. These dates do not agree closely with the dates of maximum of the beats.

DISCUSSION.

The President (Sir Gilbert Walker) said that meteorology was clearly under a great obligation to Mr. Brunt for the able manner in which he had enabled conclusions to be drawn regarding the fundamental question of periodicities in European weather: and it would only emphasize the value of his paper to describe some provisional conclusions derived from a preliminary study of the probabilities involved. He (the President) had examined two out of the twelve series, Milan rainfall and Edinburgh pressure; and, accepting the view that the amplitudes of the Fourier sub-multiples were independent as well as adequate for the reproduction of the original series, he pointed out that between the periods of 12 and

[23] A. E. Douglass, *Monthly Weather Review*, 1909, p. 225, finds a period of 32.8 years in the growth of trees.

[24] Brückner, *Klimaschwankungen*, (*Holtzel, Wien*), 1890, p. 232.

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25 months there were approximately 52 independent periods where Mr. Brunt had given data for 31; and between 60 and 120 months, 10 independent periods where Mr. Brunt had calculated 19 amplitudes. Of the periods not exceeding 10 years the standard deviation of monthly rainfall was 63 mm., and the probable value of an amplitude given by pure chance was 3.03 mm.: accordingly, when 35 of the actual independent amplitudes found by Mr. Brunt was less and 37 greater than 3.03 mm., the agreement was satisfactory. Also the probable value of the greatest of 75 given by pure chance was 7.9 and the greatest found was 7.3, apart from the annual period of 15.5 mm. Similarly, for the periods not less than 11 years the probable value of an amplitude produced by chance was 2.35 units, so that the probable value of the greatest of 10 independent ones was 4.6 units: the greatest found was not larger than 4.1.

Turning to periods in Edinburgh pressure not exceeding 10 years, the probable value of an amplitude given by chance was .0077in. and the probable value of the greatest of 75 independent ones was .020in.; the actual greatest, apart from the annual one, was .020in. Similarly, for periods of not less than 11 years the probable greatest of eight independent chance amplitudes was .014in. and the actual greatest was .015in. From these figures the natural inference was that in Milan rain and Edinburgh pressure there were no periods more marked than would be produced by pure chance, or that none of the periods in these two elements were real. Further, the argument for reality based on the occurrence of the same period in various places had little weight in view of the influence of such factors as the N. Atlantic circulation on the general conditions in N.W. Europe. The President looked forward to a more adequate examination of the materials provided by Mr. Brunt's admirable work.

Mr. F. J. W. Whipple showed a pair of diagrams (see p. 27) which he had prepared to exhibit the amplitudes and phases of the various components which Mr. Brunt had found in the analysis of London temperatures.[1] He pointed out that the scatter of the points on these diagrams was generally such as might be attributed to chance. There were, however, some special features of interest.

The period with the greatest amplitude was 12⅓ months. An oscillation with that period would make beats with the annual oscillation so that the annual range of temperature would appear to vary. The maximum range would recur after 37 years. This would seem to be the way in which the Brückner cycle manifested itself in the temperature records for London and the other places for which the analysis gave the 12⅓-month period.

Again, the period of 13 months was conspicuous in the London temperature analysis. This implied beats every 13 years. To accord with Wagner's results mentioned in the paper (*vide* p. 18) beats should have occurred at intervals of 16 years. That would have meant an apparent oscillation with a period of 12.8 months. Unfortunately, that period was not considered by Mr. Brunt in the periodogram analysis. Mr. Whipple also expressed the hope that Mr. Brunt would make a comparison between the results of his investigations of periodicity in London temperatures. The comparison would indicate which periods tended to persist.

Dr. L. F. Richardson writes:—So much having been so thoroughly

[1] *London, Phil. Trans. R. Soc.*, A., **225**, 1925, p. 269.

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LONDON TEMPERATURE—HARMONIC COMPONENTS [AFTER BRUNT]

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done, it seems ungrateful to ask for more; yet if 12⅓ months is put forward as a significant period it will be desirable to investigate the periodogram between 12 and 12⅓ months, for it might happen that all periods between 11⅔ and 12⅔ months had large amplitudes.

Mr. D. BRUNT in reply pointed out that the worker on periodicities is always working near the margin between the real and casual. He did not feel that the points put forward by the President, or the lantern slides shown by Mr. Whipple, could be taken as in any way proving that the periods found were unreal. A large number of the amplitudes worked out must in any case be casual in their incidence, and the superposition of a relatively small number of real variations upon these could not vitally affect the general distribution of the whole. It is to be hoped that Sir Gilbert Walker will extend his analysis to all twelve series, so that the question of the reality of the periods can be discussed from the standpoint of the theory of probability. The President inferred from the data for Milan that no periods were more marked than would be produced by mere chance, but he surely is not justified in inferring from this that none of the periods are real. With regard to his reference to the influence of the North Atlantic circulation on the general conditions over Europe, this argument can only be accepted if it is shown that the same periods come out in the North Atlantic. If this were so, it would support the view put forward by the writer of the paper that the periods in question are periods of the general circulation, rather than the contention of the President.

With reference to the remarks of Mr. Whipple concerning beats of the periods near one year, and his desire for a comparison with the earlier investigations of London temperatures, a note had been prepared before the meeting dealing with these points. It is given as an addendum to the paper.

The request of Mr. Richardson would involve a great deal of labour. It should be noted that the influence of the 12-month period cannot account for large amplitudes at 11⅔ and 12⅔ months. It is suggested that the surest way of investigating the lengths of periods near a year is to look for the beats in the annual variation.

Mr. F. J. W. WHIPPLE writes:—I should be glad if you could find room in the *Journal* for the diagrams which I showed when Mr. Brunt's paper on periodicities was before the Society.

Analogous diagrams have been used previously in comparing the amplitude and phases of oscillations with the same period, as for example[1] in the harmonic analysis of the diurnal variation of pressure for different months, but the application of the idea to periodogram analysis is, I believe, novel.

Little explanation of the diagrams is necessary. In his analysis Mr. Brunt represents a simple periodic oscillation by the alternative forms $C\cos nt + S\sin nt$ and $R\cos(nt-\phi)$. In my diagrams C and S are the ordinate and abscissa of a representative point, R is the radius vector and ϕ is the vertical angle measured clockwise from the top of the diagram. R represents the amplitude of the oscillation, while ϕ is what Brunt calls the phase of the maximum. The meaning of this phrase can be seen from an example; if ϕ is 60°, *i.e.*, one-sixth of 360°, the interval between the date for which $t=0$ and the first subsequent maximum of the oscillation in question is one-sixth of the period.

[1] *Q.J.R. Meteor. Soc.*, **43**, 1917, p. 283.

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It may also be pointed out that when it is desired to express the harmonic term in the more usual form $R \sin(nt + \alpha)$, the diagram is equally useful: the angle α is the vectorial angle of the representative point according to the ordinary convention of analytical geometry, being measured anti-clockwise from the axis of abscissæ.

The numbers against the representative points in my diagrams give the lengths of the periods in months or years as the case may be. To avoid overcrowding, only the numbers for the larger amplitudes are inserted in the month-diagram. The grouping of the "shots" in the month-diagram is fairly even round the centre: in the year-diagram the "shots" are mostly to the left. The periods represented in this diagram are all greater than ten years. For every period above fifteen years the angle ϕ is greater than 180°, so that each of these long-period terms was actually decreasing in 1763. This is consistent with the fact that, according to the statistics which Brunt has adopted, London was colder on the average in the years 1763-1767 than in any subsequent group of five years.

The way in which the analysis is affected by including the early years in the analysis is striking. For the sixteen years period Mr. Brunt gives $C = 0.00$, $S = -0.11$. Now it is found that the leading terms in the Fourier series representing the data for the first sixteen years 1763-1778 have the coefficients $C = 0.21°F.$, $S = -1.87°F.$ There are nine sixteen-year periods in the whole run 1763-1918 and each of these contributes its share to the average. The contribution of the first of the nine is $C = 0.02°F.$, $S = -0.21°F.$ It is clear that the contributions from the remaining periods are overwhelmed. One is apt to say that a discontinuity in the data owing to some flaw in the observations is of no importance in harmonic analysis. This example shows the danger of such an assumption.

In conclusion, I should like to urge that the time has come for a definite pronouncement on the general question of periodicity in atmospheric phenomena. Can we not say now that the movements of the atmosphere are so complicated that it is impossible for them to have any definite periods except such as are dictated by astronomical circumstances? The relation of the earth to the sun determines the annual and daily periods. There may be indirect effects of lunar action. Mr. Baxendell has found recently that off-sea winds at Southport are stronger when the tide is rising than when it is falling; the mean range for the months of his investigation was from 24.1 miles per hour, three hours before high water, to 21.1 miles per hour, four hours after high water (Southport Auxiliary Observatory, Annual Report 1925, p. 10). The moon crosses the meridian at Southport about 1½ hours after high water. Research has shown that there is no substantial effect of the moon and it is exceedingly improbable that the weather is governed at all by the planets.

Variations on account of changes in the amount and character of solar radiation in the widest sense cannot have periods more sharply defined than those of the solar changes. Whereas a periodicity of about eleven years is to be looked for, there is no good reason to expect periods sub-multiples of eleven years. An analogy may make this last point clear. The variations of temperature just below the surface of the ground have an annual period and the higher harmonics are considerable. In the variation of temperature at greater depths these higher harmonics are inappreciable. The higher harmonics in the cause are eliminated

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in the effect. That the eleven-year period is not more conspicuous in weather records is perhaps surprising. If a sub-multiple of the period were consistently conspicuous, it would, in my opinion, be more surprising.

THE PERIOD OF SIMPLE VERTICAL OSCILLATIONS IN THE ATMOSPHERE.

By D. BRUNT, M.A., B.Sc.

[Manuscript Received November 8—Read November 17, 1926.]

If the atmosphere is in stable equilibrium, any small element which is displaced in the vertical direction, upward or downward, is acted upon by forces of restitution which are proportional to the distance through which the element is displaced. The subsequent motion of the particle should therefore be a simple harmonic motion about its original position. The derivation of the period of this oscillation is as follows.

Let the height above the earth's surface be denoted by h, and let the absolute temperature at height h be denoted by T, so that T is a function of h. For simplicity, we shall assume that a unit mass of air, originally at height h and temperature T is displaced to a height $h+dh$ where the surrounding air at the same level has a temperature $T+dT$. The displaced air takes up a temperature $T+dT'$ at its new level. The motion being supposed adiabatic, $dT' = -\beta dh$ where β is equal to the adiabatic lapse rate.

In its displaced position the air is acted upon by the following forces:—

(1) Its own weight,

and (2) the force of buoyancy equal to the weight of air displaced by it at its new level.

The first of these is equal to g and acts downward. The second is equal to $g\frac{T+dT'}{T+dT}$ acting upward.

The resultant force acting upon the displaced mass is therefore $-g+g\frac{T+dT'}{T+dT}$ acting vertically upward. This may be written

$$g\left\{-1+1+\frac{dT'-dT}{T}\right\}$$

neglecting small quantities of the second order, or

$$\frac{g}{T}\left\{\frac{dT'}{dh}-\frac{dT}{dh}\right\}dh,$$

$$\text{or } -\frac{g}{T}\left\{\beta+\frac{dT}{dh}\right\}dh.$$

The condition that this resultant force shall tend to restore the displaced mass towards its original position is that $\beta+\frac{dT}{dh}$ shall be positive, or that $\beta > -\frac{dT}{dh}$. In other words, the lapse rate must be less than the adiabatic.

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The resultant force on unit mass is equal to the acceleration produced, and may therefore be written in the form $\frac{d^2}{dt^2}(dh)$. We then have

$$\frac{d^2}{dt^2}(dh)+\frac{g}{T}\left(\beta+\frac{dT}{dh}\right)dh=0.$$

With the proviso that $\beta+\frac{dT}{dh}$ is positive, this equation represents a simple harmonic motion about the original position, with a period of oscillation

$$2\pi\Big/\left\{\frac{g}{T}\left(\beta+\frac{dT}{dh}\right)\right\}^{\frac{1}{2}} \text{ seconds.}$$

In an isothermal atmosphere, $\frac{dT}{dh}=0$ and the period of oscillation is $\frac{2\pi}{\sqrt{g\beta/T}}$. Taking T as $300\,a$, we find a period of oscillation of 350 seconds, or rather less than 6 minutes. For inversions, the period of oscillation is less than this, and as the lapse rate increases from zero up to the adiabatic value, the period increases indefinitely from 6 minutes upward. It can be readily seen that if the lapse rate is $(1-1/n)$ times the adiabatic the period is $350\sqrt{n}$ seconds. Thus if the lapse rate is one half the adiabatic, the period is $350\sqrt{2}$ seconds, or just over 8 minutes. When the lapse rate is two thirds the adiabatic, the period is $350\sqrt{3}$ seconds, or almost exactly 10 minutes. When the lapse rate becomes equal to the adiabatic there is no oscillation and any displaced particle will stay where put. For lapse rates greater than the adiabatic, instability occurs, and the displacement increases exponentially.

If the air is saturated, β must be interpreted as the adiabatic lapse rate for saturated air, or roughly half its original value. The period of oscillation in an isothermal saturated atmosphere is then 8 minutes, it being assumed that raindrops do not fall out. This assumption is probably justified in the case of oscillations of such short period.

Thus the periods of oscillation which correspond to the most frequently observed lapse rates lie between 6 and 10 minutes. Periods of this duration are frequently observed on the microbarograph traces, and it is in the hope that the simple result given above may be of assistance to those investigating microbarograph traces, that the present note has been written.

Note added November 15, 1926.

The above discussion formed a portion of one of a series of lectures on Dynamical Meteorology delivered at the School of Meteorology during the years 1921-1924. Since this paper was sent to the Society my attention has been drawn by Dr. L. F. Richardson to a paper by Väisälä, *Soc. Scient. Fennica, Comm. Phys. Maths.*, **2**, 19, 1925, p. 38, in which the same formula for the length of the period is derived.

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DISCUSSION.

Mr. F. J. W. WHIPPLE pointed out that the author of the paper had not demonstrated that an element of the atmosphere could perform simple oscillations of the type that was suggested. One element could not move without displacing the surrounding air. The investigation of the motion presented a very difficult problem in hydrodynamics. The real virtue of the paper was that it indicated the order of magnitude of the period of possible oscillations. If the problem of a localised vertical oscillation could be solved, the difference between the actual lapse rate and the adiabatic lapse rate would appear in the solution. The period of oscillation would be some multiple of the period given in the paper and vary inversely as the square root of the difference in question. Mr. Whipple thought this was as far as it was legitimate to go.

In reply to Mr. Whipple, Mr. BRUNT writes:—I did not fail to realise that while the real problem of oscillations in the atmosphere is a hydrodynamical problem, the paper discusses an artificial problem in particle dynamics. I find it difficult, however, to believe that a solution by hydrodynamical methods can alter the form or magnitude of the solution very considerably, and this is borne out by the fact that my formula gives the right order of magnitude for the microbarograph periods. The paper is put forward as a useful basis for the investigation of microbarograph records, as it gives a provisional relationship between the period of oscillation and the lapse rate, and it is nowhere suggested that the simple oscillation which gives the period derived is itself the physical mechanism behind the periodic oscillations shown by the microbarograph.

The Soaring Flight of Birds.

A note published in a recent number of *Mitteilungen des Aeronautischen Observatoriums Lindenberg* contains an account of an interesting observation of the soaring flight of a stork made during a kite-balloon ascent on May 2, 1926. The bird was kept under constant observation through a range-finder for no less than 45 minutes, during which time not the slightest motion of the wings could be detected. The readings of the range-finder show that during an interval of twenty minutes the height only varied between 502 m. and 518 m., the distance from the point of observation increasing from 1625 m. to 2000 m.

The kite ascent furnishes particulars of the conditions in the free atmosphere. In the lowest 120 metres the lapse rate was adiabatic and the wind velocity increased from 9 m/s. at the surface to 15 m/s. Above this surface layer there was an inversion about 300 m. thick, in which the temperature increased by 1°.8 C. and the wind velocity increased further to 22 m/s. Above that level the velocity fell off rapidly, and at 1750 metres it had the comparatively low value of 4 m/s. Instinctively the bird had selected the most favourable level for its flight, in this case the level of maximum wind velocity at the top of the inversion. Turbulence at the surface of separation suggests itself as the source of support.

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FIG. 1.—Clouds resembling animals. Above, crabs crawling; below, boars or rats.

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FIG. 2.—Butterfly cloud (Tyo-Tyo-Gumo).

FIG 3.—Forerunner of a line squall. Drifting towards E., photographed facing S.

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FIG. 4a.

FIG. 4b.

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FIG. 4c.

FIG. 4d.

FIG. 4.—Screwing up of towering cumulus.

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FIG. 5.—Screwing structure of cirrus.

FIG. 6.—Cumulo-Nimbus belonging to a "front" formation.

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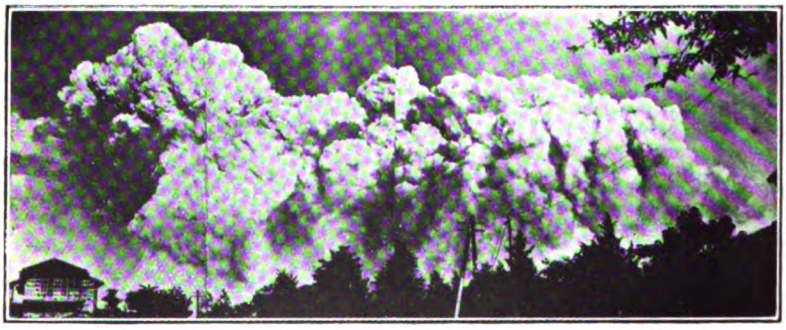

FIGS. 7 & 8.—Gigantic cumulus over Tokyo, September, 1923.

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CLOUD STUDIES.

By Dr. S. FUJIWHARA.

§1. Clouds near the Horizon as the Sign of Changing Weather in Japan and in Europe.

In the course of the discussion at the International Congress in London, 1921, which resulted in the nomination of a Commission for the study of clouds, it was mentioned by Prof. T. Okada and Colonel F. A. Chaves that certain cloud forms commonly observed in Japan and in the Azores are apparently not seen in Europe and are not included in the *International Cloud Atlas*.

In order to draw further attention to this interesting point the present author made a study of the Japanese cloud forms at the Central Meteorological Observatory, Tokyo. He desires here to acknowledge help received from Professor T. Okada and from the Society for Commemorating the Tri-Centenary of Tōshōgū.

From ancient times eastern peoples have studied clouds from the point of view of weather forecasting. For example, 80 kinds of rain clouds and 60 kinds of fine weather clouds were known among Indian statesmen in the 4th century B.C.

In Japan and China there was also some knowledge of weather science. After a long search among old Japanese books, the author was able to find some ten of these dealing with meteorological matters, two of which are now presented before the meeting.[1] They deal with the laws of weather forecasting in China and Japan and they are illustrated with rough pictures of clouds.

From as far back as the fifteenth century A.D., the observation of clouds near the horizon, up to an altitude of some 30 degrees, has been considered in Japan to be as important from the point of view of weather forecasting as that of upper clouds. As a sign of changing weather, special significance is attached to a form of clouds having some resemblance to animal shapes such as hog, rat, crab, snake or dragon, etc. (Fig. 1). It generally appears in groups of small clouds of dark hue in contrast to the surrounding grey, whitish or blue sky. Sometimes this cloud shows a marginal brightness as cumulus occasionally does; but it is by no means the cumulus of fine weather. Sometimes, on the contrary, it exhibits a dark marginal rim. This cloud if included in one of the international cloud forms, would be classed as Fr. Cu. or St. Cu., but it is neither the ordinary Fr. Cu. nor St. Cu. The cloud only appears before a change in the weather and any observer can easily and definitely recognise it after having seen it a few times. On the evening of September 22, 1926, the author, in company with M. P. Wehrlé, observed it from the train on a journey from Innsbruck to Vienna. On the following day the weather was showery at Vienna and continued so until the 24th. The author had similar experiences at Rax, near Vienna,[2] at Lindenburg, near Berlin[3] and in the train while passing through

[1] These books are now in the Library of the Society.

[2] Observed with Prof. W. Schmidt, September 26, 1926. It rained the following day in Vienna.

[3] Observed on October 12, 1926. It rained next day in Berlin.

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Russia, so that it seems likely that this kind of cloud is as well worth study in Europe as in Japan.

§2. Solitary Clouds.

A solitary cloud, such as is shown in Fig. 2, is also considered to be a sign of changing weather in Japan. This cloud is white and has turbulent structure and appears only in one, two or three very small flakes in a blue sky, quite isolated from other clouds. This cloud may be classed as Ci. Cu. or Al. Cu., but it is not ordinary Ci. Cu. or Al. Cu. and may be easily distinguished. In Japan the cloud has the name "*Tyo-Tyo Gumo*," which means butterfly cloud.

On the morning of September 12, 1926, the author observed this cloud with Dr. H. G. Cannegieter at the northern end of the Lake of Zürich and on the following day the weather became unsettled. This cloud must not be confused with the forerunner of a line squall (Fig. 3). The latter cloud is also white and flaked, but more turbulent, having many cusps and it always appears in groups in blue sky. When the latter cloud moves rapidly in the usual direction of the shift of the line of discontinuity, the typical squall cloud, with or without precipitation, may be expected to appear after some thirty minutes to four hours. The author observed this forerunner with Professor Okada at Fürstenwalde, near Lindenburg, at about 11.30 h. on October 12, 1926, and a dark squall cloud with strong winds arrived at Lindenburg at about 13.00 h.

The isolated *tyo-tyo* cloud is a sign of an approaching cyclone depression or typhoon which is advancing much more slowly than the squall line. One may expect the weather to become stormy or rainy some 18 to 48 hours after the appearance of *tyo-tyo* cloud.

The author would like to recommend the further investigation of such clouds in various localities and hopes that reference to them may be included in the synoptic weather messages in due course.

§3. Screwing Structure of Cloud.

Screwing motion is a combination of rotational and translational motion, it is often conspicuously shown by fine weather cumulus. Fig. 4 shows a typical example. When a cone of cumulus is observed from the side we may often notice on it, bulges alternately on the two sides at successive heights. This is but a vertical view of screwing structure in three dimensions. Screwing structure may often be identified also in clouds of cirrus type (Fig. 5).

§4. Two Kinds of Cumulo Nimbus.

As is well known, there are two kinds of thunderstorms, *i.e.*, heat thunderstorms and "front" thunderstorms. The cloud belonging to the former is the ordinary Cu. Nb. developing from cumulus. The clouds belonging to a cold front are not mere cumulus. They are generally a mixture of cirrus, alto-cumulus, strato-cumulus and cumulo-nimbus, but on some occasions of thunder we can only observe roll cumulus, which later develops into cumulo-nimbus. In this case, cumulo-nimbus takes on quite

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a different form as shown in Fig. 6. The cloud now has a linear structure along the front and, at the same time, it has a very precipitous appearance on the front and back. It is suggested that a specific name be given to this kind of cumulo-nimbus.

§5. The Greatest Cumulus Producing Experiment Ever Made.

Illustrations of cumulus clouds produced by fires have often appeared in *The Monthly Weather Review* and other publications. They resemble ordinary fine weather cumulus. Devastating fires were experienced as a sequel to the disastrous earthquake which shook Tokyo and the neighbourhood on September 1, 1923. The fire in Tokyo continued for 40 hours, from noon on the 1st to the morning of the 3rd. Yokohama, Odawara, Atsuki and Minadsuru also suffered severely from fire. Gigantic cumulus clouds were seen over Tokyo and Yokohama even from a distance of 20 miles. The cloud had a very sharp outline with very fine, small spherical bulges, appearing silver white in the sunshine—much more silver white than does ordinary cumulus. Photogrammetrical investigation by K. Kikuti proved that the height of the top of the cloud was generally about 6 km. and sometimes exceeded 8 km. In Fig. 7 a sketch and in Fig. 8 a photograph of the cloud are shown.

Meteorological observations taken in the Central Meteorological Observatory during the earthquake and fire are given in Table I. and for comparison with values at neighbouring stations where no fire occurred. From the curve we can estimate the temperature of the air over the field of fire and its neighbourhood and the horizontal gradients of temperature and density. Wind measurements are also shown in Table I. Comparison of these figures with the weather charts of the period shows that a strong gale reaching 21.8 metres per second was produced by the action of the fire. Relative humidity was very low, but the absolute humidity was increased as is suggested by comparing the humidities at Kumagai and Tokyo (Fig. 9).

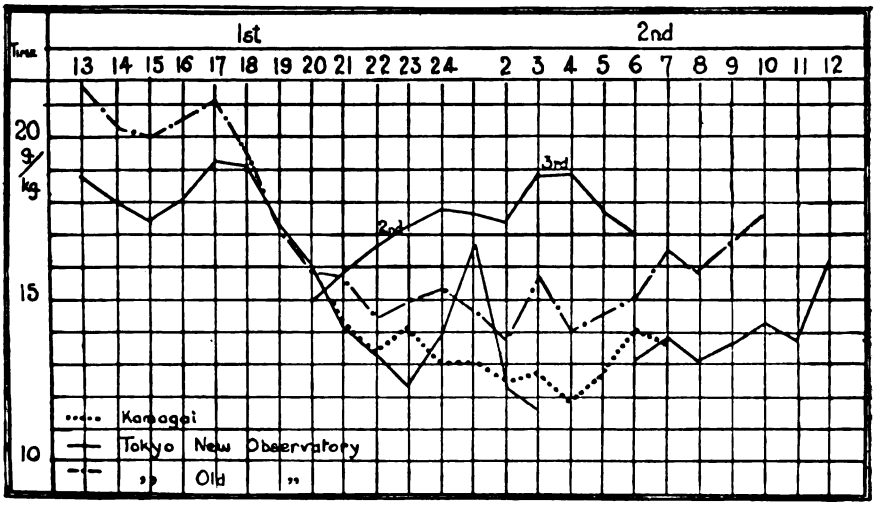

Fig. 9.—Comparison of specific humidities at Tokyo and Kumagai, September, 1923.

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TABLE I.—METEOROLOGICAL OBSERVATIONS TAKEN

A. Air Pressure. (mm.)+700.

Hour.	1	2	3	4	5	6	7	8	9	10	11	12
Date.												
1.	56.6	55.8	55.4	55.0	54.4	54.1	53.5	53.0	52.3	51.6	51.2	49.0
2.	51.9	52.1	52.4	52.8	53.4	53.7	54.2	54.4	54.5	54.2	53.9	53.0
3.	55.2	55.0	54.8	54.8	54.8	54.9	55.0	54.9	54.9	54.7	54.3	54.4
1.	56.7	55.9	55.5	55.1	54.7	54.3	53.6	53.2	52.4	51.9	51.3	50.4
2.	52.0	52.2	52.6	52.8	53.4	53.8	54.3	54.4	54.5	54.1	53.9	54.0
3.	54.9	54.7	54.6	54.4	54.6	54.9	54.9	54.8	54.8	54.6	54.3	54.0
1.	54.7	54.4	53.7	52.7	52.1	51.3	50.4	50.0	48.8	48.3	47.1	47.0
2.	50.0	50.1	50.2	50.7	51.1	51.5	51.7	51.9	...	...	...	...

B. Air Temperature (Deg. C.).

1.	25.9	25.8	25.0	25.6	26.0	26.2	26.6	26.9	26.3	26.7	26.3	28.7
2.	45.2	40.8	41.4	35.1	30.3	30.3	26.3	26.1	27.7	27.1	27.1	29.3
3.	27.4	27.3	26.7	25.5	25.4	25.5	26.5	27.7	27.7	28.4	28.1	28.1
1.	25.9	26.1	24.5	25.6	26.2	26.7	26.5	26.5	27.2	26.7	28.5	30.5
2.	25.6	25.4	25.7	25.0	25.1	24.8	26.7	28.5	27.1	26.9	26.2	26.7
3.	25.7	25.4	25.1	25.0	24.8	26.3	27.9	28.4	28.3	29.6	29.1	27.7
1.	...	24.7	...	24.3	...	25.0	...	25.0	...	25.0	...	29.0
2.	...	23.0	...	22.7	...	24.8	...	27.8	...	27.2	...	25.4
3.	...	24.5	...	24.5	...	24.6	...	26.7	...	27.6	...	26.5
1.	23.7	23.6	23.5	23.6	23.4	23.9	24.0	24.3	25.1	25.3	25.7	28.2
2.	24.6	24.2	24.1	22.2	21.0	21.4	24.8	26.6	...	30.0	...	...
3.	...	23.4	...	...	...	23.0	...	...	...	27.8	...	...
1.	25.5	25.5	25.2	24.8	25.3	26.0	26.0	26.1	25.9	26.7	26.4	29.0
2.	24.1	23.9	23.5	22.9	22.8	22.7	23.7	25.8	28.1	28.8	27.1	25.9
3.	25.4	25.4	25.5	25.5	25.1	25.3	25.8	26.7	28.3	28.5	28.8	28.4

Humidity.

1.	82	83	87	83	84	84	83	84	90	85	88	77
2.	27	25	23	...	...	48	63	63	57	63	60	75
3.	78	79	84	86	83	82	77	76	78	74	79	80
1.	93	93	95	96	92	89	91	93	96	88	88	79
2.	59	62	71	74	78	80	79	72	79	78	80	85
3.	97	98	96	96	95	90	84	82	80	78	77	79
1.	...	93	...	95	...	93	...	93	...	93	...	86
2.	...	90	...	91	...	89	...	79	65	75	...	82
3.	...	96	...	98	...	94	...	86	...	77	...	88
1.	96	97	97	98	98	98	99	99	97	97	95	77
2.	74	71	82	82	91	92	82	72	...	65	...	69
3.	...	94	...	...	...	97	...	...	...	77	...	...

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DURING THE GREAT FIRE AT TOKYO, SEPTEMBER, 1923.

Tokyo, New Observatory.

13	14	15	16	17	18	19	20	21	22	23	24	Hour.
												Date.
49.8	49.1	48.8	48.6	49.4	49.5	50.1	50.6	50.6	50.9	51.2	51.2	1.
54.0	53.6	54.0	53.8	54.0	54.3	55.0	55.4	55.5	55.5	55.5	55.4	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Sinagawa, Southern Suburb.
49.7	49.3	48.9	49.0	49.4	49.7	50.5	50.9	51.0	51.2	51.6	51.9	1.
53.8	53.6	53.8	53.8	53.9	54.4	54.9	55.2	55.4	55.4	55.3	55.0	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Kumagai, about 40 km. north of Tokyo.
46.9	46.8	46.9	47.2	47.5	48.0	48.5	48.9	49.1	49.6	49.7	49.9	1.
...	...	...	...	...	...	...	...	...	...	...	...	2.
												Tokyo, New Observatory.
28.1	29.5	29.7	30.0	28.3	29.1	29.8	29.0	30.3	31.9	32.7	37.1	1.
26.9	27.4	27.1	27.5	27.3	27.2	27.4	27.5	27.2	27.1	27.4	27.4	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Sinagawa.
30.3	31.1	30.1	29.4	28.7	27.4	26.5	26.8	26.6	26.6	26.6	26.0	1.
27.0	27.0	26.8	26.7	26.5	26.0	25.9	25.8	25.7	25.7	25.8	25.9	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Nisigahara, North-Westerly Suburb.
...	29.6	...	29.8	...	28.2	...	27.0	...	26.0	...	23.7	1.
...	26.0	...	26.1	...	25.6	...	25.8	...	25.5	...	24.4	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Kumagai.
30.9	30.5	30.5	31.3	30.7	28.3	26.1	25.3	25.9	25.7	24.8	25.3	1.
...	29.6	...	...	...	25.4	...	...	...	24.0	...	...	2.
...	...	...	..	...	...	...	...	...	...	...	...	3.
												Kagomati, N.W. part of Tokyo.
30.1	30.7	30.7	30.9	31.2	30.0	28.6	27.8	27.1	26.4	26.2	25.6	1.
26.1	26.8	26.6	26.9	26.9	26.6	26.3	26.5	26.4	26.2	25.8	25.5	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Tokyo, New Observatory.
76	67	65	66	78	73	64	62	52	44	30	35	1.
72	67	68	69	69	71	64	64	69	72	75	77	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Sinagawa.
74	68	74	76	77	89	90	84	74	71	67	65	1.
81	80	82	83	87	88	91	92	92	93	95	96	2.
...	...	...	...	...	...	...	...	...	...	...	...	3.
												Nisigahara.
...	76	...	76	...	85	89	80	...	78	...	90	1.
88	85	...	84	...	86	...	81	...	87	...	95	2.
...	...	..	...	...	...	...	...	...	...	...	...	3.
												Kumagai.
74	72	71	69	74	77	78	76	73	68	75	74	1.
...	63	..	...	...	84	...	...	...	91	...	...	2.
...	...	...	...	...	...	...	...	...	...	...		3.

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TABLE I.—Meteorological Observations taken during

Wind.

Hour.		1	2	3	4	5	6	7	8	9	10	11	12
Date.													
1	Dir.	SSE	ESE	ESE	SE	SE	SE	SE	SSE	S	S	S	SSW
	Vel. m./s.	5.5	5.5	7.9	5.0	6.0	7.8	9.8	9.5	11.2	11.0	10.8	12.3
2	Dir.	NNW	N	N	N	NNW	NNW	NW	N	SSW	SW	SW	SW
	Vel. m./s.	16.9	15.4	13.8	10.5	10.2	7.9	7.9	5.4	4.6	4.4	5.1	5.0
3	Dir.	SSE	SSE	SE	S	S	S	S	S	S	S	S	S
	Vel. m./s.	7.0	8.4	7.3	6.7	4.3	4.7	5.9	8.1	10.2	9.6	11.8	11.2
1	Dir.	SE	ESE	ESE	SE	SE	SSE	SE	SSE	SSE	S	S	SSE
	Vel. m./s.	5.3	8.0	9.3	7.2	7.3	8.7	8.6	12.5	10.3	10.9	7.1	8.8
2	Dir.	NWW	...	...	...	...	...	...	SE	...	SW	...	SW
	Vel. m./s.	4.2	5.3	4.7	4.1	4.4	2.8	0.3	0.5	0.1	1.7	0.1	0.5
3	Dir.	E	E	SE	S	S	S	SSE	SSE	SSE	SSE	SSE	S
	Vel. m./s.	4.3	5.4	2.6	1.8	0.8	1.2	3.8	4.8	4.8	7.5	7.6	8.0
1	Dir.	E	E	E	ESE	ESE	ESE	ESE	SE	ESE	ESE	SE	SSE
	Vel. m./s.	2.5	2.9	3.6	6.0	5.4	5.8	5.4	3.3	9.8	6.3	6.6	5.0
2	Dir.	W	WNW	WNW	NNW	WNW	NW	WNW	NNW	...	...	...	...
	Vel. m./s.	8.3	8.0	6.1	3.2	2.5	1.3	2.3	3.3	...	...	...	...

Making use of all the observed values a rough calculation shows that the velocity of ascent of the heated air must have been from 1 m/s. to 15 m/s. over a rather wide area and more than 70 m/s. over a very small area where the air temperature rose as high as 100°C.

By actual observation of the cloud at the time, the order of magnitude of the ascensional velocity of the cloud head was proved to coincide with the above calculation. That is, the head of the whole cumulus ascended with a velocity, more or less, of 1 m/s. and the smaller heads rose more quickly with velocities of 17 m/s.

The height of the cloud base can be calculated from the value of the temperature (about 45°C.) and the humidity (23 per cent.) at the ground level. As a rough measure this gives a height of from 2-3 km. If the temperature of the air outside the area of the fire be assumed below 30°C. with a lapse rate of 5.5°C. per km. (actually calculated from observations), the ascending column becomes more unstable after reaching the rain stage and ascends to the top of the stratosphere or the stratum of some other temperature inversion. But if the surrounding air has a temperature above 31°C. the ascending column becomes stable at a height below the rain stage and no cloud is formed. There is thus a critical value of external temperature below which a gigantic cloud column reaching upwards to the stratosphere must form and above which no cloud is formed.

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THE GREAT FIRE AT TOKYO, SEPTEMBER, 1923—*continued.*

Tokyo, New Observatory.

13	14	15	16	17	18	19	20	21	22	23	24		Hour.
													Date.
S	SSW	SSW	SW	S	W	W	WNW	NNW	NNW	NW	NNW	Dir.	1
11.7	11.3	11.0	10.7	13.7	14.5	13.1	18.1	18.5	19.2	21.8	17.6	Vel. m./s.	
SW	SSW	SW	S	S	S	S	S	S	S	S	S	Dir.	2
6.9	5.9	5.7	5.8	8.7	8.2	6.6	7.9	6.2	5.0	4.8	6.1	Vel. m./s.	
...	...	...	...	...	...	...	...	...	...	...	...	Dir.	3
...	...	...	...	...	...	...	...	...	...	...	...	Vel. m./s.	
													Sinagawa.
S	S	S	SSW	SSW	WSW	WSW	...	WNW	WNW	WNW	WNW	Dir.	1
8.0	7.5	6.1	5.1	4.6	2.3	2.0	0.0	2.8	4.1	4.7	4.5	Vet. m./s.	
SSW	SSE	S	S	S	...	...	...	...	...	...	...	Dir.	2
0 7	2.9	1.1	1.3	1.2	0.2	0.0	0.0	0.0	...	...	...	Vel. m./s.	
...	...	...	...	...	...	...	...	...	...	...	...	Dir.	3
...	...	...	...	...	...	...	...	...	...	...	...	Vel. m./s.	
													Kumagai.
SSW	WNW	WNW	WNW	WNW	NW	WNW	WNW	WNW	WNW	WNW	W?	Dir.	1
3.3	4.2	3.3	3.4	2 4	3.5	2.8	5.0	7.5	...	5.2	8.3	Vel. m./s.	
...	...	...	...	...	...	...	...	...	...	...	...	Dir.	2
...	...	...	...	...	...	...	...	...	...	...	...	Vel. m./s.	

CORRESPONDENCE AND NOTES.

The Meteorological Characteristics associated with the North-Westerly Type of Weather at Cranwell, Lincolnshire.

The following is a *précis* of a paper by Messrs. W. H. Pick and G. A. Wright dealing with the local characteristics at Cranwell of the "north-westerly" type of weather. The paper is the fifth and last of the series by the authors on weather types at Cranwell. Summaries of the previous four numbers have already been published in earlier numbers of the *Journal*. The classification into types was based on an examination of 7h. (G.M.T.) synoptic charts published in the *Daily Weather Report* of the Meteorological Office, London, for the period January 1920 to October 1925. As with the previous papers, the manuscript is, by the kindness of the authors, lodged in the Society's Library, where it may be consulted if further details are desired than it is possible to give in this brief account.

Summary.

(*a*) Summer is the season most favouring the occurrence of the north-westerly type.

(*b*) Considering conditions at 13h., the type is slightly more cloudy than normal in spring and summer, and is slightly less cloudy than normal in autumn and winter.

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(*c*) There is a total absence of any bad or poor visibilities at any hour in spring, an almost entire absence of bad or poor visibilities at any hour in summer, and a total absence of good or very good visibilities at 01h. in spring.

(*d*) At all seasons the type is almost entirely free from fog.

(*e*) The type is marked by considerably lower percentages of rain days than is normal at all seasons and especially so in winter.

(*f*) The type is marked in winter and autumn by the occurrence of hail days considerably above the average in number, and in spring and autumn by the occurrence of snow or sleet days above the average in number. Except in autumn it is not a thundery type.

(*g*) The type is seldom accompanied by severe frosts, either on the ground or in the screen, but ground frosts, even if not severe, are comparatively common in winter.

(*h*) The type is, on the whole, not one of high relative humidity except at 01h. in summer.

Heavy Rains in Hongkong.

Mr. L. Gibbs sends some interesting particulars of a heavy rainstorm which was experienced at Hongkong during the early morning of July 19, 1926. It occurred with the filling up of a typhoon which, passing on a northerly track, crossed the coast about 100 miles to the east of the Colony. The storm was accompanied by a severe thunderstorm and lasted for nine hours, during which time 20.43in. of rain were measured. The falls per hour varied from 0.54in. at the commencement to a maximum of 3.96in. from 3 a.m. to 4 a.m. From 5 a.m. to 8 a.m. measurements from two to three inches per hour were made. Then an increase to 3.20in. per hour occurred, and an hour later rainfall had ceased.

For comparison he sends also particulars of two other intense storms. The first occurred in two parts, the chief falls being measured from 7 a.m. to noon on May 29, 1889 (total for seven hours, 9.98in.), and then after a period of comparative quiescence a further measurement of 16.16in. was recorded between midnight and 6 a.m. on the 30th. On this occasion the storm was accompanied by almost continuous thunder and lightning. Totals of three inches or more per hour were measured during five hours of the storm, the maximum 3.40in. per hour being measured between 3 a.m. and 4 a.m. on May 30. The second storm occurred on October 30 and 31, 1923, when dry, bright winter weather has usually set in on the South China coast. This storm was less intense than either of the other two. The maximum fall per hour (1 a.m. to 2 a.m.) was 2.82in., the total for the eight hours during which the storm lasted being 12.58in.

The storm of July 19, 1926, was thus one of the most severe, if not indeed the heaviest, ever recorded at Hongkong. The fall of 3.96in. per hour measured from 3 a.m. to 4 a.m. is 0.48in. greater than the amount given by Hann[1] in the table of large amounts of rain of one hour's duration. This latter measurement (3.48in.) was made during the storm of July 15, 1886, giving a maximum intensity per minute of 1.47 mm. compared with one of 1.68 mm. per minute measured during the July storm of this year.

[1] Hann-Suring, Lehrbuch der Meteorologie. *Vierte Auflage, Leipzig*, 1926, p. 385.

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THE NILE FLOOD AND WORLD WEATHER.

By E. W. BLISS, M.A.

(Memoirs of the Royal Meteorological Society, Vol. I., No. 5).

[Published October, 1925—Read November 17, 1926.]

SUMMARY.

Correlation coefficients are given with pressure, temperature, rain, ice and wind, and it is shown (*a*) that the Nile flood takes part in the southern oscillation as a member of the first group, (*b*) that equatorial temperatures are in inverse relation to the Nile flood, and (*c*) that the winter North Atlantic circulation varies inversely with the preceding Nile flood. St. Helena pressure has no contemporary relationship with the Nile flood. A formula is derived for prediction on June 1 with a joint coefficient of 0.72.

DISCUSSION.

The PRESIDENT (Sir Gilbert Walker) remarked that the similarity of the variations of the Nile floods to those of the Indian monsoon rainfall had long been known; but Mr. Bliss had shown that the Nile is an even better representation of the southern oscillation in world weather —the oscillation between the Pacific and the Indian Oceans. Abyssinia also resembles India and Japan in that the effect of its rainfall as a world factor is greater than that of the pressure at sea level in the region of rainfall. Cairo, in summer, tends to vary with the Azores, and oppositely to Iceland, in the following winter; and a high Nile is thus followed by a feeble Atlantic circulation. The contribution of Mr. Bliss was important in linking up the winters of N.W. Europe with the oscillations of the southern hemisphere.

[I should have stated that the association of abundant India monsoon rainfall with weak contemporary Atlantic trade winds and low temperature in Germany in the succeeding winter was pointed out by W. Georgii in the *Annalen d. Hydrographie u. Maritimen Meteorologie,* January, 1923.][1]

Mr. D. BRUNT suggested that as Mr. Bliss had investigated a very large number of records, and had finally selected the three which proved most favourable for his purpose, it would have been of interest to see whether the coefficients of correlation which he put forward could be regarded as stable. The investigation would have gained in interest if Mr. Bliss had evaluated the coefficients of correlation for the years 1882-1915, and had then used his formula to forecast the Nile flood for the next ten years, giving a comparison with the actual observations. Mr. Brunt also pointed out that he had compared Mr. Bliss's figures for Nile flood 1869 to 1905 with the annual mean temperatures at Stockholm during those years, and found high Nile floods and high temperatures at Stockholm in the years 1878, 1887, 1890, 1894 and 1903, and low values for both these factors in the years 1881, 1888, 1893 and 1902. It therefore appears that there should be a positive correlation between

[1] Note added 1st December, 1926.

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temperatures at Stockholm and Nile floods. Now Table III. shows that Greenwich temperatures show negative correlation with the Nile flood except in one quarter of the year. He therefore wished to ask Mr. Bliss whether Greenwich and Stockholm were situated in belts which were negatively correlated with one another as regards temperature, or whether it was possible that in winter Stockholm temperatures might be negatively correlated with Nile floods, although the annual figures gave a positive correlation.

Dr. C. E. P. Brooks congratulated Mr. Bliss on the amount of information which he had condensed into the paper. He wished to remark on two points, the first being the correlation with St. Helena pressure, which was .6 for the first sixteen years but only .06 for 1892 to 1920. Looking at Table I. one sees that from 1869 to 1898 more than 80 per cent. of the departures of the Nile flood were positive, while from 1899 to 1925 more than 80 per cent. were negative. At the same time St. Helena pressure was rising steadily, and this would partly account for the falling off of the positive correlation coefficient. But there was more in it than that; from 1899 to 1924 the correlation between St. Helena pressure and Nile flood was $-.52$, indicating an actual reversal of the relationship. The rise of pressure at St. Helena is probably due to the progressive northward movement of the South Atlantic anticyclone, and Miss W. A. Quennell had suggested to him that this might account for the reversal of the correlation. It seems probable that variations of pressure in the equatorial trough and in the anticyclone tend to be opposed, the former agreeing with the Nile flood and the latter, like Cairo pressure, opposed to it. In the early years when the anticyclone lay far south, St. Helena was in the equatorial trough and therefore its pressure had a positive correlation with the flood, but the northward movement brought St. Helena within the anticyclonic region and the correlation became negative.

In this country we are naturally most interested in the relations between the Nile flood and subsequent weather in western Europe, and we are told that after a high Nile flood the pressure difference between the Azores and Iceland is smaller than usual. The relationship is obviously not direct, so it must be due to the relations of both variants to some third variant. Table III. of the paper shows that in general the Nile flood has its largest negative correlations with equatorial temperatures, while the three largest positive coefficients are with Hebron, Labrador, in the north, directly influenced by cold Arctic water, and with Punta Arenas and Cape Pembroke in the south. That is, a large temperature difference between low and high latitudes gives a poor flood. It is generally understood that the strength of the atmospheric circulation depends on this temperature gradient, and the Azores-Iceland pressure difference is to some extent a reflection of the atmospheric circulation. Hence perhaps the relation between Nile floods and British weather. But why should a good atmospheric circulation give poor floods? The planetary wind, both in Abyssinia and India, is the north-east trade; the rain-bearing monsoon develops in defiance of this planetary wind. Hence the stronger the planetary circulation, the weaker the monsoon and the Nile floods. He hoped Mr. Bliss would investigate this point, if he had not already done so.

Mr. L. C. W. Bonacina said that he did not quite like to speak of "active" or "passive" zones (to quote Sir Gilbert Walker's phrase) in this correlation work, as though conditions at one place directly

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affected those at another. One must surely regard a correlation between one place and another as an outward expression of deep-seated inter-relations in the atmosphere, the physical mechanism of the correlation not being in most instances traceable. In reality, the atmosphere must be a veritable mine of such correlations, and the more we can dig out, the nearer we shall be to seeing the underlying mechanism.

The reference made by Mr. Bliss to the source of the moisture for the Abyssinian rainfall interested him because some years ago an animated discussion took place at a meeting of the Royal Geographical Society as to whether the Indian Ocean or Atlantic Ocean provided the moisture. But as with all hard-fought points, both views are partly right: for if one looks at a mean wind and pressure map for the season of the rains, there is every indication that air current from both oceans must frequently converge on to the Abyssinian highlands, and convergence of air currents is one of the primary conditions for the formation of practically all rains.

Mr. E. W. Bliss writes in reply to Mr. Brunt's question that he has not worked with Stockholm temperature, but judging from other stations it seems probable that the winter temperature there is negatively correlated with the Nile. The coefficients of Greenwich, except in winter, are small, and he did not think that any marked opposition exists between Stockholm and Greenwich temperatures. With reference to Mr. Brooks's remarks, he had noticed the change in 1899 from a series of high to one of low floods, but had found no explanation of it. He had not studied the effect of trade winds on the monsoon.

Plotting Isopleths of Relative Humidity.

For the purpose of computing relative humidity from the readings of the ordinary dry and wet bulb thermometers, or the ventilated psychrometer, it is sometimes useful to plot isopleths of the relative humidity on a diagram in which the co-ordinates are the readings of the dry and wet bulbs respectively. For most purposes this process is sufficiently accurate and is less laborious than the use of tables.

Disadvantages arise, however, in the tendency for the lines to crowd together at the cold ends of the scales, thereby making the scale of humidity inconveniently small, while the fact that the lines are all curved with the exception of that for 100 per cent. makes it tedious to plot them accurately.

Both of these difficulties may be overcome by using logarithmic paper. It is, of course, necessary to choose the best point on the logarithmic scale from which to start the temperature scales, but when this has been done it is possible to obtain isopleths which are nearly parallel straight lines. Such are comparatively easy to draw and are convenient for interpolation. Using Jelinek's tables for the wet and dry bulb and the Fahrenheit scale, 100 deg. is best placed at 9.5 on the logarithmic scale, 90 deg. at 8.5, 80 deg. at 7.5, and so on. A small portion of such a graph is given in the figure showing the isopleths for 100, 75, 50 and 25 per cent. humidities. Tables for use with the ventilated psychrometer are based on the formula

$$e_w - e = B/1500\,(T_D - T_W)$$

where B is the barometric pressure in millibars, T_D and T_W are the dry and wet bulb temperatures respectively in Centigrade degrees, e_w is the

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saturated vapour pressure in millibars corresponding to T_w, and e is the required vapour pressure. Such tables, using the absolute scale, are best dealt with by placing 300 deg. at 4.5 on the logarithmic scale, 290 deg. at 3.5, and so on.

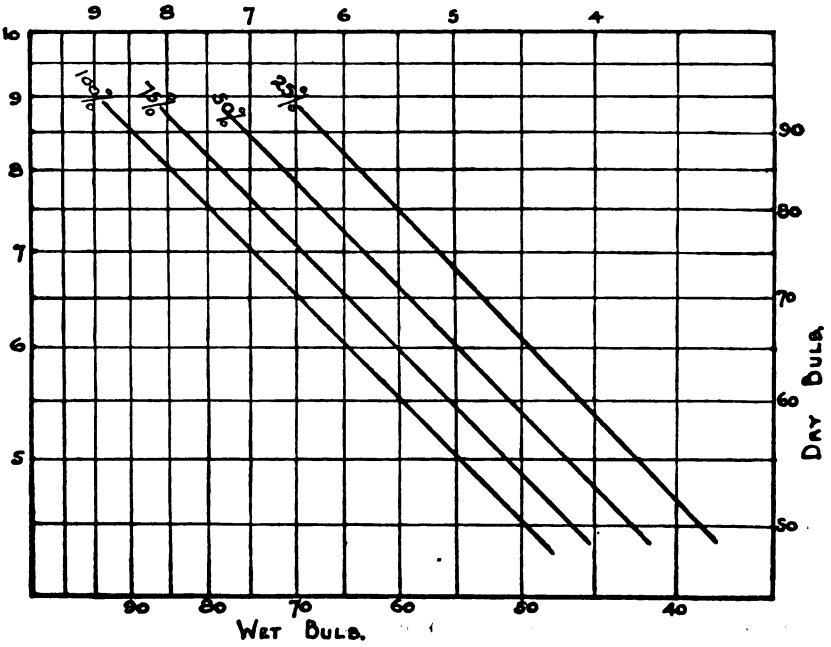

FIG. 1.—Isopleths of Relative Humidity.

Unfortunately, with logarithmic paper of the size usually obtainable the humidity scale becomes rather contracted, and paper in which the ratio 10 : 1 is represented by at least 50 cms. is needed for convenient reading.

Exactly the same method can be used to form graphs connecting dry bulb temperaure, dewpoint and relative humidity; it is only a question of finding by trial the most suitable region of the logarithmic scale.

L. H. G. DINES.

Kew Observatory.
December 9, 1926.

Davos Meteorological Observatory.

A valuable extension has lately been added to the Davos Physico-Meteorological Observatory by the establishment of a branch station at Gornergrat (10,269 ft. above sea-level) in addition to the already existing branch station at Muottas-Muraigl (8,038ft.).

Particulars as to the conditions under which work may be taken up at the Observatory have already been given in the *Meteorologische Zeitschrift* for 1924, page 82, where mention was also made of certain vacancies for co-workers, with the possibility of free board and residence for a suitable period, together with a free ticket on the Rhaetian Railway starting at Landquart. Free tickets are also granted for the mountain railways leading up to Muottas-Muraigl and Gornergrat, and the local hotels offer considerably reduced terms to co-workers of the Observatory.

F. LINDHOLM.

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SOME MEASUREMENTS OF TEMPERATURES NEAR THE SURFACE IN VARIOUS KINDS OF SOILS.

By N. K. JOHNSON, M.Sc., and E. L. DAVIES, M.Sc.

[Manuscript received September 25—Read December 15, 1926.]

Introductory.

A study of the temperatures in different soils and at different depths within the soil is of importance in agriculture and also in a number of problems connected with the economic life of a country. The present series of observations was carried out with the object of investigating the temperature changes in the extreme uppermost layers of the soil. The standard practice of measuring the temperature at depths such as 1 ft. and 4 ft. fails to take account of the very large diurnal changes which occur near the surface of the soil and which are of great importance from various points of view.

In the account which follows, particular attention is devoted to the extremes of temperature experienced just below the surface of the soil. In addition, the rate of travel of the diurnal heat wave downwards through the soil is examined, and also the rate at which its amplitude is quenched out as it penetrates the soil. From both of these the conductivity of the soil is calculated, the two values so obtained being in fairly good agreement.

Procedure.

The experiments were carried out on Salisbury Plain, the observations extending throughout the year 1925.

For the surface temperature measurements six plots of ground, each 1 m. square, were prepared with the following surfaces:—

1. Tar-Macadam.
2. Bare earth.
3. Grass.
4. Sand.
5. Rubble.
6. Bare clay.

The material constituting the surface was 15 cm. deep in each case, and the tops of the surfaces were flush with the adjoining ground.

In each of these beds two brass tubes 1 cm. in diameter and 10 cms. long were buried horizontally with their axes 1 cm. below the surface. Inserted into these tubes were maximum and minimum thermometers—one pair to every plot.

In addition to these thermometers, a platinum resistance thermometer element was buried at a depth of 1 cm. in the sand bed, and gave a continuous record of the temperature on a Cambridge Instrument Company's thread recorder.

The downward penetration of the daily temperature changes was measured in the natural grass-covered chalky soil of the district. For this purpose two bulbs of a Negretti and Zambra

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TABLE I.—MEAN MONTHLY SOIL TEMPERATURES IN DEGREES FAHRENHEIT.

	MAXIMUM.							MINIMUM.							RANGE.						
	Air	Tarmac.	Earth.	Grass.	Sand.	Rubble.	Clay.	Air.	Tarmac.	Earth.	Grass.	Sand.	Rubble.	Clay.	Air 4-feet.	Tarmac.	Earth.	Grass.	Sand.	Rubble.	Clay.
Jan.	46.9	46.6	44.7	43.2	45.4	44.7	44.1	35.0	34.3	35.0	37.2	35 6	34.5	35.1	11.9	12.3	9.7	6.0	9.8	10.2	9.0
Feb.	47.6	51.1	46.7	44.0	48.8	47.4	48.2	33.4	32.5	34.6	36.8	33.3	33.2	33.7	14.2	18.6	12.1	7.2	15.5	14.2	14.5
Mar.	47.8	59.5	51.1	45.2	53.3	50.9	51.4	31.7	31.7	33.3	36.2	31.1	32.3	32.8	16.1	27.8	17.8	9.0	22.2	18.6	18.6
April	53.3	72.3	61.1	52.6	63.7	58.9	62.3	35.0	36.1	36.9	41.4	35.4	35.6	37.2	18.3	36.2	24.2	11.2	28.3	23.3	25.1
May	60.0	85.9	74.2	69.4	76.4	71.2	70.4	42.6	45.2	45.1	49.8	44.5	44.6	45.3	17.4	40.7	29.1	19.6	31.9	26.6	25.1*
June	71.2	108.6	95.7	84.7	95.1	88.0	76.3*	45.7	50.0	50.7	55.9	48.4	49.9	55.5	25.5	58.6	45.0	28.8	46.7	38.1	20.8*
July	72.2	104.7	88.7	82.4	89.9	...	...	51.0	53 8	54.4	58.4	53.4	53 6	55.3	21.2	50.9	34.3	24.0	36.5	...	...
Aug.	67.7	89.6	76.3	68.9	79.3	75.9	77.5	50.5	52.4	52.3	55.1	51.4	51.7	54.1	17.2	37.2	24.0	13.8	27.9	24.2	23.4
Sept.	61.0	77.5	65.4	61.2	69.3	67.3	66.6	42.8	42.9	43.8	47.9	42.5	42.4	44.3	18.2	34.6	21.6	13.3	26.8	24.9	22.3
Oct.	59.8	68.8	61.2	55.6	63.8	61.6	58.4	42.8	43.7	47.7	47.9	43.3	43.6	45.3	17.0	25.1	13.5	7.7	20.5	18.0	13.1
Nov.	45.4	50.6	47.1	44.1	46.5	46.0	45.1	34.1	32.0	34.9	38.1	32.8	34.0	36.3	11.3	18.6	12.2	6.0	13.7	12.0	8.8
Dec.	42.6	...	...	...	...	...	...	30.9	...	...	...	...	...	...	11.7	...	...	...	...	...	...

* See page 51.

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mercury-in-metal thermograph were employed, one being kept at 2.5 cms. below the surface, and the other placed at various times at depths of 7.5 cms., 15.25 cms. and 30.5 cms.

These thermometer bulbs were installed by digging a small pit and boring a series of horizontal holes penetrating about 30 cms. into the side of the pit. The holes were, of course, staggered so as not to be beneath each other. The thermometer bulbs, which were about 15 cms. long, were inserted into these holes and the pit filled in. The bulbs were thus covered by undisturbed soil.

Results.

The records of temperatures are now available for the year 1925, except that the maximum and minimum temperatures in the different plots are missing for December.

The results of analysing the temperature observations are given in Table I. and are shown graphically in Figs. 1 to 3.

Table I. contains the mean values of the maximum and minimum temperatures recorded in each type of soil during each month. The mean values of the maximum and minimum air temperatures as measured at a height of 1.2 m. in a standard Stevenson screen are also given. In Fig. 1, the uppermost full lines are the mean soil maxima and the lower full lines are the mean soil minima. The two broken lines show the mean maximum and mean minimum air temperatures.

The outstanding features of these curves are as follows:—

1. In the summer the mean soil maxima are considerably higher than the maximum air temperatures. In June the mean maximum for the tarmac was 108°F. which is 37°F. in excess of the air maximum. In the case of grass-covered ground the mean maximum for the same month was 85°F., or only 14°F. above the air maximum. The values for all the other types of soil lay intermediately between these.
2. In mid-winter the mean soil maxima are all practically equal to each other and almost identical with the mean air maxima (about 45°F.).
3. The mean minimum soil temperatures throughout the year agree very closely with the minimum air temperatures in the screen. The only exception occurs in the case of the grass-covered soil in which the minimum averages about 5°F. higher than the air minimum.

   The mean value of the minimum in summer is about 53°F. and in winter about 35°F.

During July a certain number of maximum readings are missing for the rubble and clay beds so that means cannot be taken for these. The mean maximum and minimum values plotted for the clay bed for June also call for remark. Comparison with the other curves appears to make it fairly certain that the maximum is too low and the minimum too high. It seems likely that this bed must have been disturbed about this time, possibly by the cracking of the clay.

Turning now to the extreme maximum and minimum temperatures recorded in each kind of soil for each month, the values are

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shown by the full line graphs of Fig. 2. The dotted graphs show the maximum and minimum air temperatures on the same days as those on which the extreme maximum and minimum soil temperatures occurred respectively.

The general characteristics of this set of graphs are similar to those of Fig. 1, the only differences being in the absolute magnitudes of the temperatures. Thus the highest temperature recorded during the year in the tarmac was a value of 128°F. In the case of the grass-covered soil the value was 101°F.

In mid-winter, however, no soil temperature in excess of 55°F. was recorded.

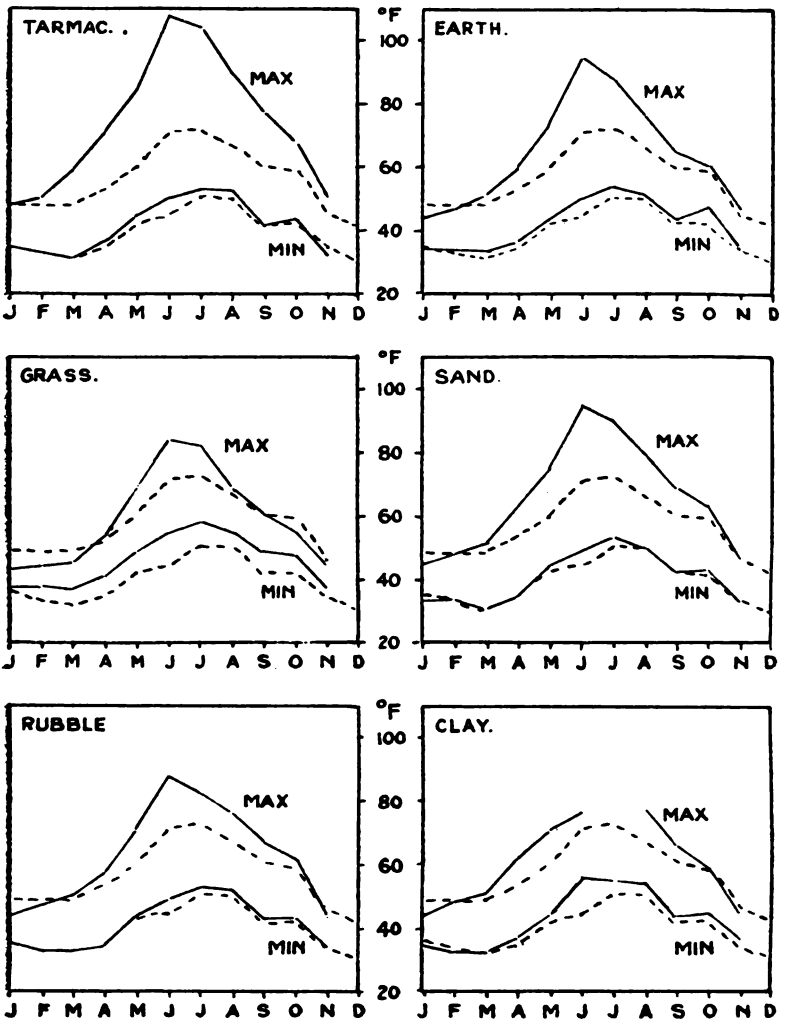

Fig. 1. Mean Diurnal Soil Maximum and Minimum Temperatures for each Month.
(Full lines—Soil temperature.)
(Broken lines—Screen temperature.)

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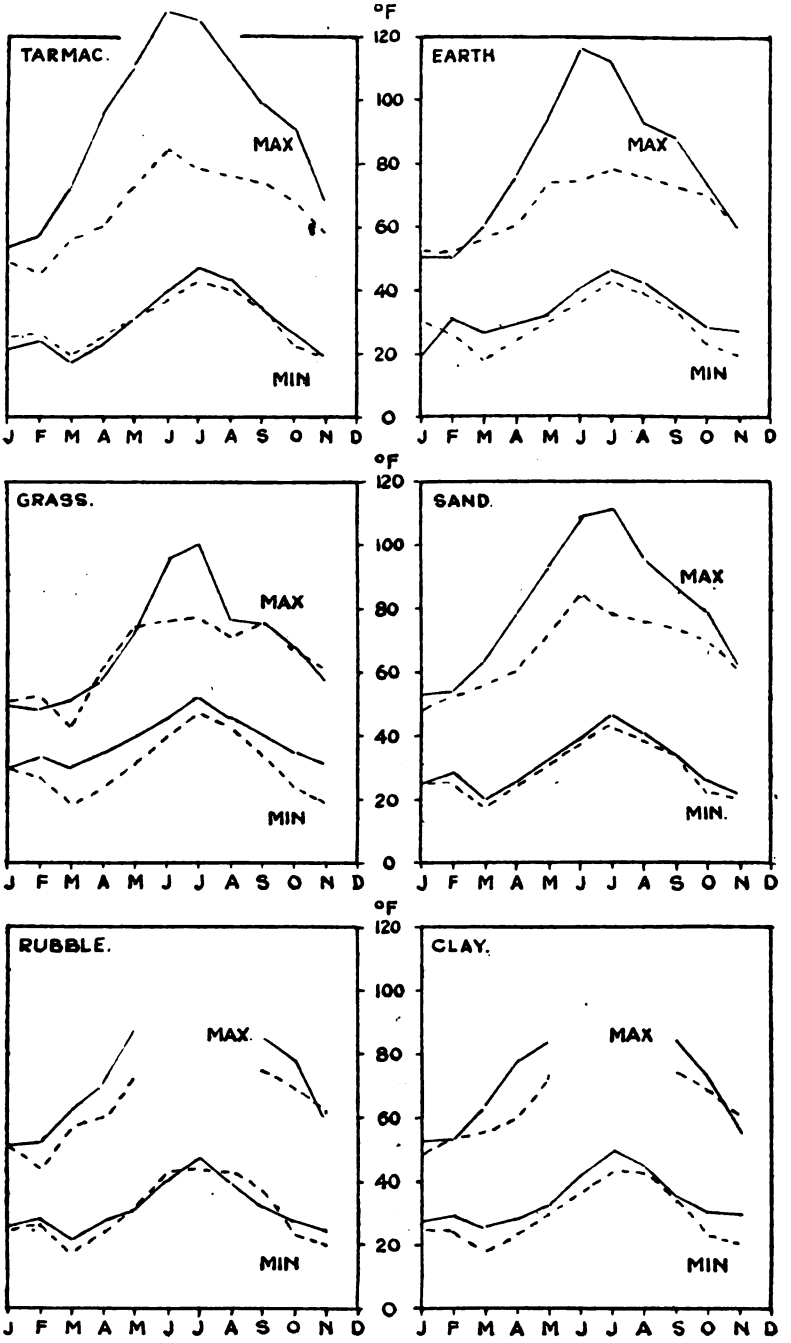

Fig. 2. Extreme Maximum and Minimum Temperatures for each Month
(Full lines—Soil temperature.)
(Broken lines—Screen temperature.)

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Temperatures as low as 20°F. are to be expected in mid-winter, except perhaps in the case of grass-covered soil in which the lowest temperature recorded is 31°F.

In mid-summer it appears that the soil temperature never falls below about 45°F.

The average values for the diurnal range of temperature in each kind of soil are dealt with in Table I. and Fig. 3. As before,

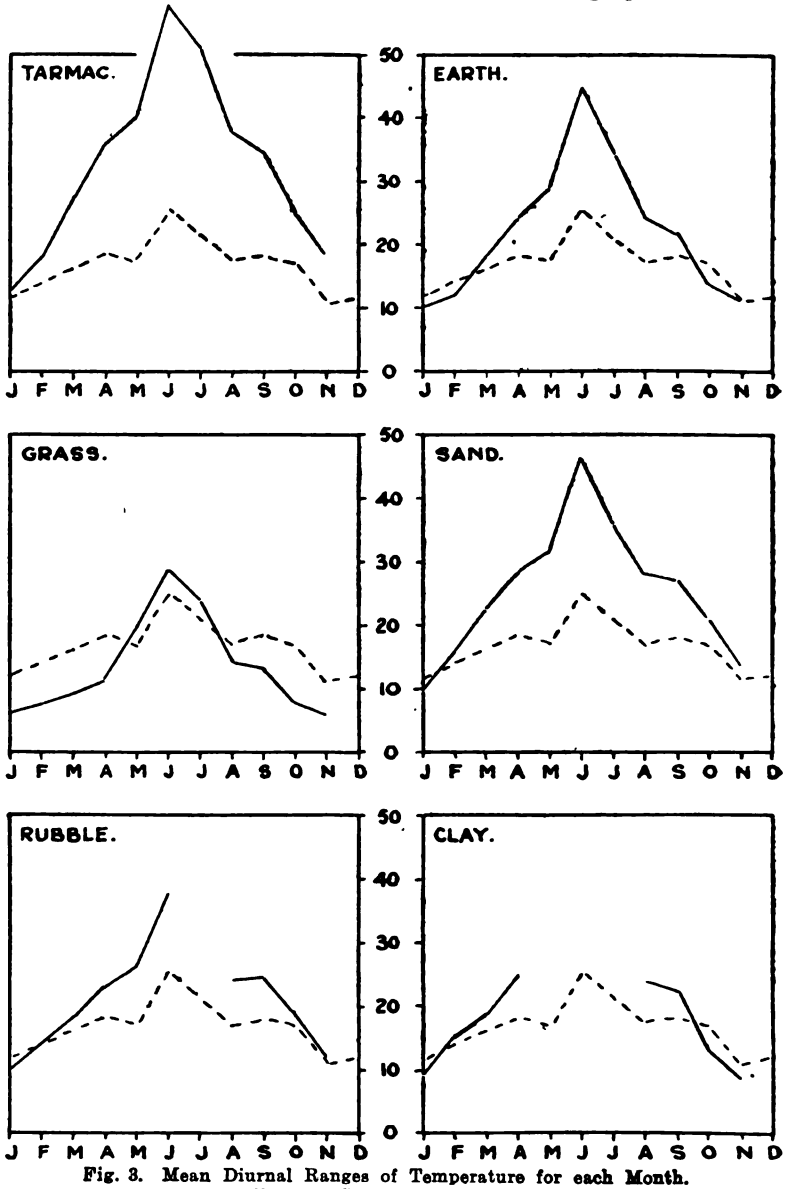

Fig. 3. Mean Diurnal Ranges of Temperature for each Month.
(Full lines—Soil temperature.)
(Broken lines—Screen temperature.)

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the full lines refer to soil temperatures and the broken lines to air temperatures.

With the exception of the grass-covered soil, in mid-winter the diurnal range is in every case about 10°F., which agrees closely with the diurnal variation of the air temperature. In the case of the grass-covered soil the range is only about 6°F. at this time of the year.

In mid-summer the mean diurnal range is about 59°F. in the case of tarmac and only about 29°F. in the case of the grass-covered soil. The corresponding diurnal range in the air temperature was 25.5°F.

The clay observations show an irregularity for June, as has already been remarked, and possibly also for May.

Discussion of Results.

1. *Conductivity of the Soil.*

These ranges of temperature may be used to determine the conductivity of heat in the soil:—

It may be taken that no serious error will result if it is assumed that the daily variation of temperature at the surface can be represented by

$$\theta = A \sin 2\pi \frac{t}{T}$$

where θ is the temperature, A half the diurnal range, t the time and T 24 hours.

This assumption is not strictly accurate since the curves are not as a whole true sine curves (see sub-section 2 below). In view, however, of the difficulty of deciding in every case the position of the zero line about which the variation could be regarded as oscillating, it was considered better to measure the extreme diurnal range and assume a simple sine curve.

The standard conductivity equation gives (see for example Carslaw, *Conduction of Heat*, p. 49):—

$$\theta = Ae^{-bz} \sin\left(\frac{2\pi t}{T} - bz\right) \quad . \quad . \quad . \quad (1)$$

where z is the depth below the surface in cms.

K is a function of the conductivity given by the relation

$$K = \frac{\text{conductivity}}{\rho\sigma}$$

where

ρ is the density of the soil and
σ its specific heat.

The quantity b is determined by the relation $b^2 = \pi/TK$.

Hence the ratio of the daily ranges R_1 and R_2 at two depths z_1 and z_2 is given by

$$\log_e \frac{R_1}{R_2} = b\,(z_2 - z_1) \quad . \quad . \quad . \quad . \quad (2)$$

Equation (2) is used here to determine the quantity K from the diurnal ranges of temperatures found for the various depths by means of the self-recording thermometer referred to in the last

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paragraph of Section II., z_1 is taken as 2.54 cms. throughout, z_2 in turn is 7.5 cms., 15.25 cms. and 30.5 cms. In Fig. 5 $\log_e R_1/R_2$ is plotted against $(z_2-2.54)$; an additional point is obtained on this graph by deducing the ratio when z_2 is 1 cm., taken from Fig. 4. The slope of the optimum straight line through these points gives the constant b, which is found to be:—

$$0.0846 \text{ cms.}^{-1}$$

thus

$$K=\frac{\pi}{Tb^2}, \quad T=8.64\times10^4 \text{ secs.}$$

therefore

$$K=5.08\times10^{-3} \text{ cm.}^2 \text{ sec.}^{-1}.$$

The scatter of the points in this graph may be due to two reasons:—

(*a*) The difficulty of measuring accurately the depth of the thermometers, due to the thickness of the bulbs and to the difficulty of knowing what level to adopt as the true surface of a grass-covered soil.

(*b*) The lower bulb of the thermograph was at 7.5 and 30.25 cms. during winter months, and at 15.25 cms. from February, 1925, to the end of the year, and it will be seen later that the ratio of the ranges is dependent upon the water content of the soil, and therefore upon the type of weather prevailing during the observations.

The ranges for the period when the lower bulb was at a depth of 15.25 cms. were divided into two groups, one for periods during which little or no rain had fallen, and one for periods during which heavy rain had fallen. It was found that the ratio of the daily range at 2.5 cms. to the daily range at 15.25 cms. was 3.65 during the drier periods and 3.3 during the heavy rainfall. This is due presumably to the fact that the water which replaces the air in the soil has a higher conductivity than the air. The values for the quantity K in these two cases are 3.5×10^{-3} and 4.1×10^{-3} respectively.

The small magnitude of this change in the conductivity is rather surprising. It is proposed to investigate this point further.

An alternative method of calculating the quantity K can be used. From equation (1) it can be shown that θ becomes a maximum when

$$t=\left\{(2n+1)\frac{\pi}{2}+z\sqrt{\frac{\pi}{TK}}\right\}\frac{T}{2\pi}$$

where n is an integer. Thus the lag between the times of maximum temperature at depths z_1 and z_2 is equal to

$$(z_2-z_1)\frac{T}{2\pi}\sqrt{\frac{\pi}{TK}}$$

Hence if L is this time lag in seconds we have

$$K=\frac{T(z_2-z_1)^2}{4L^2\pi} \quad . \quad . \quad . \quad . \quad (3)$$

These lags were obtained from the thermograph records and the

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means of a considerable number of days were taken and are given in Table II.

TABLE II.—Calculation of K from time lag.

Z_1 cms.	Z_2 cms.	L in hours.	K from eqn. (3).
2.54	7.5	1.55	5.7×10^{-3}
2.54	15.25	4.5	4.2×10^{-3}
2.54	30.5	10.1	4.1×10^{-3}
		Mean.	4.7×10^{-3}

The mean value of K given by this method agrees well with that given by the slope of the line in Fig. 5. While studying these time lags, it is of interest to note the times at which the various thermometers reach their daily maxima (see Table III.).

TABLE III.—Times at which various thermometers reach their maximum.

Depth of Thermometer in Soil.	Approximate Time (G.M.T.) of attaining maximum.
1 cm. in sand.	12.30
2.5 cm. in Chalky Soil.	14.00
7.5 ,, ,, ,,	15.35
15.25 ,, ,, ,,	18.30
30.5 ,, ,, ,,	24.00 (midnight)
Air Temp. 1.22m. above ground	15.00

It has been shown that the value for the conductivity of the soil calculated from the change of phase with depth agrees well with the value calculated from the variation of amplitude with depth.

If we adopt either of these values, then it is found that the daily maximum at a depth of 2.5 cms. should occur about 50 minutes after the surface maximum. Actually the maximum at a depth of 2.5 cms. is found from the mean of a large number of observations to occur at 14.00 h. in the grass-covered soil in which the recording thermometer elements were buried.

The true surface of the soil is difficult to define; for the purpose of measuring the depth of the thermometers, the surface is taken as the top of the soil left if there were no grass; the introduction of the grass, however, complicates matters, and the "true soil surface" lies somewhere in between the earth surface and the top of the grass. The thermometer, which is 2.5 cms. below the earth surface, is from time lag considerations nearly 6 cms. below the plane which attains its maximum at 12.00 noon. Thus the covering of grass is equivalent to about 3.5 cms. of soil. This shielding due to the grass is further demonstrated in Figs. 1-3, the grass maxima being always lower than those of the other soils and its minima higher.

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Another interesting point about Table III. is that the thermometer in the Stevenson screen does not reach its maximum until about 15.00 h. G.M.T. The explanation of this seems to be that at 12.00 noon (when the " true soil surface " reaches its maximum) there is usually a steep lapse of temperature between the surface and 1.2 m. above the ground. Thus during the hours between 12.00 and 15.00 the air at 1.2 metres is being continually supplied with heat from the surface, which is at a higher temperature; hence the temperature recorded in the Stevenson screen continues to increase until an equilibrium condition is reached, this equilibrium being reached apparently at about 15.00 G.M.T.

Before leaving the actual observations of temperature, attention may be directed to Fig. 4. in which are plotted the mean monthly ranges of the screen temperature and also of the temperatures in the soil at depths of 1 cm., 2.5 cms., 15.25 cms. These graphs show fairly clearly the relation between the temperature variations at these various positions.

2. True Surface Temperatures.

As soon as we turn to the application of the observations recorded in this paper, we are faced with the problem as to what is meant by the " surface temperature " of a piece of ground. The observations given in Tables I. to III. and Figs. 1 to 3 refer in every case to a depth of about 1 cm. below the mean level of the ground.

Let us now examine what temperatures may be expected at the true soil surface, *i.e.*, at the interface between soil and air.

From the value found for the conductivity of the chalky soil (about 5×10^{-3}) it can readily be shown that the diurnal range at the surface must be 1.09 times the range at a depth of 1 cm. If the various kinds of soil all had the same conductivities, then the diurnal ranges at their surfaces would be 1.09 times the values shown in Table III. But actually their conductivities will not be equal. It can, however, easily be shown that if the conductivity is five times as great as that of the chalky soil the factor 1.09 is only altered to 1.04, whilst if the conductivity is one-fifth that of the chalky soil the factor becomes 1.20.

It is clear, therefore, that we are fairly safe in adopting a value of 1.1 for this factor.

If now we examine the continuous records of soil temperature, it will be noticed that the average traces are not as a whole true sine curves. The day time and night time portions of the trace each approximate to portions of sine curves, but the amplitude of the former is about eight times the amplitude of the latter. Thus in mid-summer the soil temperatures may be considered as oscillating about 60°F.

In the case of tarmac the day maximum rises about 48 degrees Fahrenheit above this value, whilst the night minimum falls about 6 degrees Fahrenheit below it. In the case of earth and sand the corresponding mean day amplitudes are about 35°F. and the mean night amplitudes about 6°F.

These values all refer to a depth of 1 cm. and from what has been said above it follows that the actual surface variations will be

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about 1.1 times these values. Thus the mean mid-summer maximum for tarmac will be about 115°F. and for earth and sand about 100°F. The surface values for the summer minima and also for the winter maxima and minima will not differ appreciably from the temperatures at a depth of 1 cm.

From Fig. 2 it will be seen that the extreme temperatures of about 140°F. may be expected on the surface of tarmac and of about 130°F. on the surface of sand or earth.

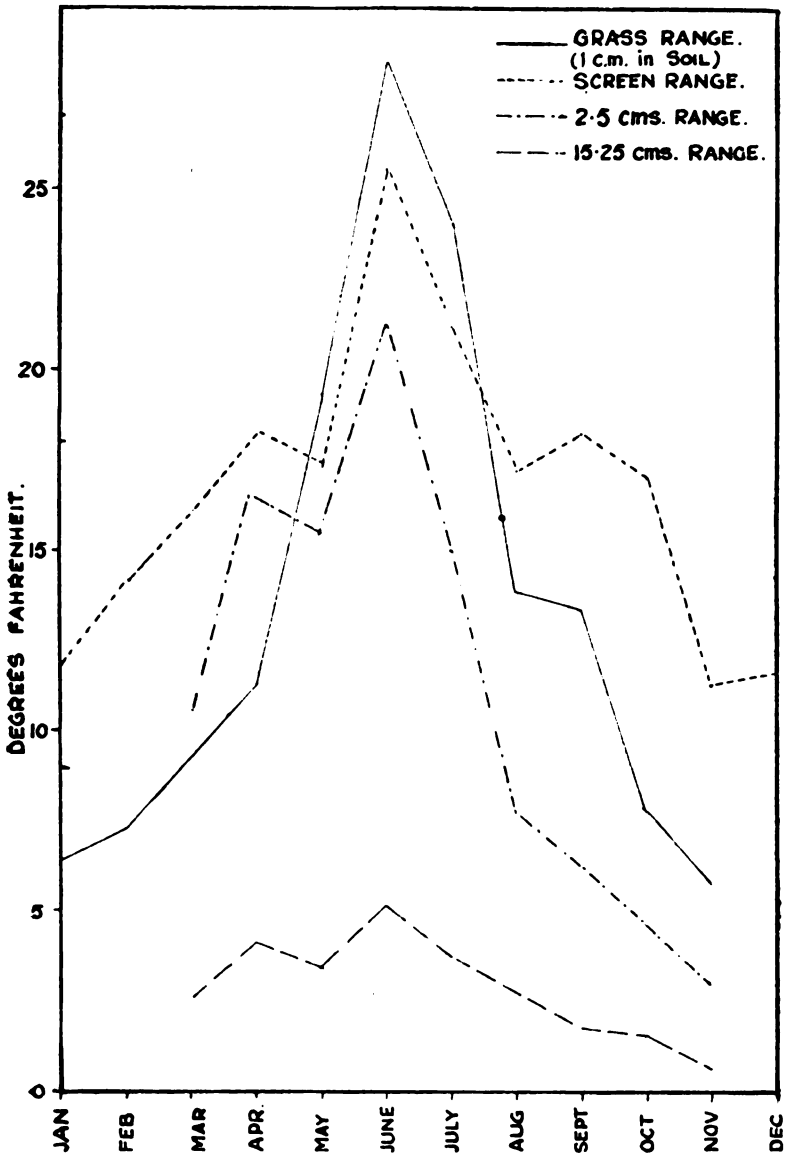

Fig. 4. Mean Diurnal Range of Temperature for each Month of 1925.

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3. *Values for the Tropics.*

A certain number of measurements of surface temperature of the soil at Agra in India (latitude 27° N.) are given by Field in *Memoirs of the Indian Meteorological Department*, Vol. XXIV., Part III., pp. 38-40.

Thus, "the outside ground surface temperature, which at 8-hours does not reach more than 15°F. above that of the air, was found, by 57 readings during 10 days in March and May, to average 39°F. in excess within the period noon to 16-hours and to reach on occasion an excess of 46°F. near 14-hours in May, when the surface soil temperature was 156°F."

Field showed further that a small thermometer, of which the bulb is just covered by the soil, gives practically the same reading as that obtained by means of a thermojunction attached to a small copperfoil proof plane moved over the surface. The normal mid-

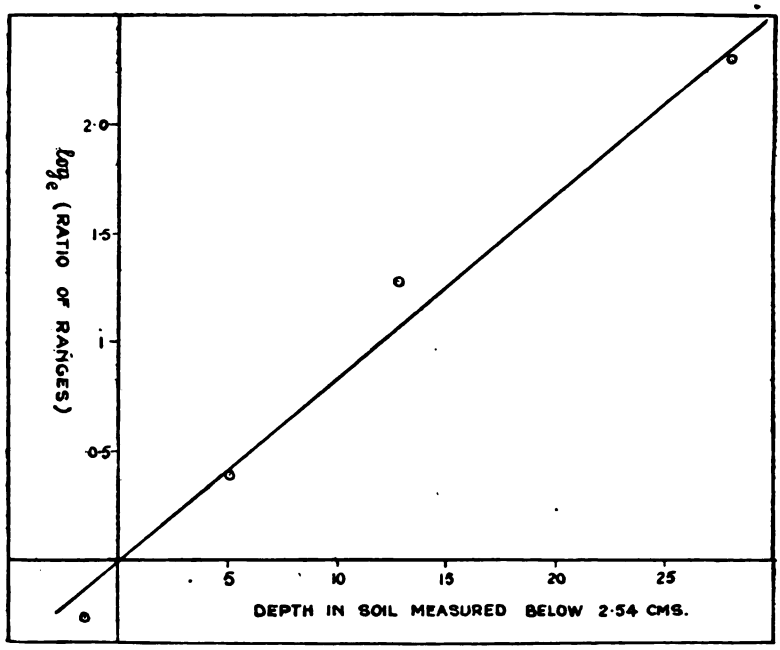

Fig. 5. Variation of Diurnal Range with Depth in Soil.

day condition at Agra is stated to be a gusty wind of two to four metres per second. An examination of our own records suggests that on a calm day in mid-summer at Agra the maximum surface temperature probably reaches 165°F.

In the Tropics this value will probably require increasing to 175-180 deg. Fahr. But even in the hottest parts of the world (air temperature in the shade equal to 135°F.) it is unlikely that the surface temperature of the soil will ever exceed 200°F.

It would be of great interest to obtain some actual observations in the Tropics to check these estimates. It would further be of

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value to ascertain to what extent the results are modified in the case of soils of types other than those considered here.

Summary.

The results are given of the measurement of the temperatures in different types of soil throughout the year 1925. It is shown that surface temperatures as high as 130°F. to 140°F. may be expected in summer with corresponding night minima of about 55°F. to 60°F. In mid-winter it is shown that the soil surface temperature follows the air temperature fairly closely with a diurnal range of only about 10°F.

The observations show the variation of temperature with depth in the soil and also the lag in the diurnal temperature wave at various depths.

Some observations made in India are then examined and the conclusion is arrived at that the highest soil temperature that may be expected is about 180°F.

DISCUSSION.

Dr. L. F. Richardson inquired if the authors could answer the puzzling question whether the air temperature was equal to the soil temperature where these two substances met, and whether measurements had been made of the reflectivity of the surfaces of the soils. Tarmac in sunshine might be expected to be hotter when fresh and black than when dusted over and grey.

Mr. L. H. G. Dines said that he had made some comparisons at Benson four years ago between a normal grass minimum thermometer and an aspirated thermometer drawing air from the same level as the bulb of the grass thermometer. They were made on frosty mornings when radiation to the sky was active, and showed that at 32°F. the grass minimum read 1°F. lower than the aspirated thermometer, the difference being larger with lower temperatures. The figures are published in the *Meteorological Magazine* for February, 1924.

Mr. L. C. W. Bonacina asked whether the authors could generalize respecting the absence of lag in the minimum daily soil-surface temperature behind the noon-day sun. The maximum and minimum appeared to be most unsymmetrically placed, the former occurring near noon, and the latter, not near midnight, but just before sunrise.

Secondly, he wished to ask with reference to the maximum temperatures liable to occur at the surface of the soil, whether Mr. Johnson had any idea what the ignition point of dry combustible matter was. Every year in spells of hot dry weather we had heath and forest fires breaking out in England, often in wild uninhabited districts where it was doubtful whether human agency could always be the cause. Might not the ignition point of vegetable matter sometimes be reached on southerly slopes beneath a June sun? Lightning, he thought, might be ruled out in this climate because in England dry thunderstorms do not occur.

He wished also to draw attention to a valuable paper by Mr. Mellish on earth temperatures in different parts of the country, published in the *Journal* for 1889.

Mr. J. E. Clark questioned whether the comparison of results from surfaces in constant shade with those from surfaces exposed to sunshine

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was worth exploring, especially in the case of tarmac. His road running ESE to WNW received practically no sunshine in winter. The shaded side was then almost always wet, while the sunny side was often dry even in weather such as that of last November. Did this suggest a cumulative radiation effect?

Mr. N. L. SILVESTER writes: May I congratulate the authors upon the interesting results of a piece of work which has involved much detailed observation.

It is unfortunate that they have not attempted to define the substances of their experiments in a more precise manner. For instance, what do they intend to convey by the use of the loose term "rubble"? Was the main constituent of the "bare earth," apart from its usual humus content, arenaceous, argillaceous or calcareous? It is assumed that as the thermometer tube was buried only 1 cm. below the surface a very fine grade of tar macadam was used. What was the proportion of tar to rock? What was the nature of the rock used (widely variable in practice) and is a layer only 1 cm. thick pervious?

Are the readings for the clay soil considered applicable to a thick clay outcropping *without* an immediate substratum of pervious rock? (I am assuming that the square metre of clay 15 cms. thick was let into a porous chalky soil.) Further, would the "bare earth" readings have differed much had the square metre been let into an impervious stratum such as clay? In other words, what would be the difference between good drainage and a waterlogged condition?

I trust the authors will not consider me hypercritical; but these questions arise from mature thought after an abortive attempt to undertake a similar investigation in 1918. Whilst at Cranwell, I took observations of a number of 1ft. earth thermometers in a similar subsoil but under different exposures, *i.e.*, in a wood, on the north and south slopes of a valley, amongst bushes, in a quarry, etc. From January to May synchronous observations were made intermittently at irregular hours. In the last month a difference of no less than 7°F. at 1ft. below the surface was recorded between a cover of conifers and an open glade sheltered by high bushes. It is hoped to bring before the Society a summary of these observations at an early date.

Mr. N. K. JOHNSON, replying to Dr. Richardson, said the authors had made no measurements of the air temperature in close proximity to the ground and consequently could not say whether it was equal to the temperature of the surface of the soil. Nor had they measured the reflectivity of the surfaces of the various soils.

The lack of symmetry in the diurnal surface-temperature curve mentioned by Mr. Bonacina is explicable in terms of incoming and outgoing radiation. The incoming radiation during the day-time clearly reaches a maximum at about noon, and the actual surface of the soil will attain to maximum temperature at the same time. On the other hand, the surface will lose heat by radiation throughout the night and will reach its minimum temperature just before the renewal of incoming radiation begins to exceed the outgoing.

With regard to Mr. Bonacina's second point, the authors consider that it is very unlikely that vegetable matter could be raised to its ignition temperature solely by the absorption of direct solar radiation.

In reply to Mr. Clark, the authors have made no observations with shaded areas, but it would appear that such surfaces must necessarily

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possess a lower temperature than those which for a portion of the time are exposed to sunshine.

The further particulars regarding the soils asked for by Mr. Silvester are as follow. The rubble consists of crushed brick, the average dimensions of the pieces being of the order of half a centimetre. The bare earth was the natural calcareous soil of the district denuded of grass. The tar macadam was the fine grade used for the surface dressing of footpaths; the nature of the rock used in it is not known. The layer of tarmac is considered to be impervious.

The readings at a depth of 1 cm. in the various soils are not considered to be greatly affected by the nature of the soil below a depth of 15 cms. The question as to the effect of the water content of the soil is dealt with in the report, but the authors do not consider that they have sufficient data to justify a consideration of " waterlogged " soils.

SOME METEOROLOGICAL OBSERVATIONS MADE AT SEA.

By N. K. JOHNSON, M.Sc., A.R.C.Sc.

[Received October 6—Read December 15, 1926.]

During last May, the writer had an opportunity of carrying out certain meteorological observations from a ship steaming eastwards in the Mediterranean Sea. The observations included accurate measurements of the vertical gradient of temperatures in the first twenty metres of air above the sea at regular intervals throughout a day and a night; and as it is believed that this is the first occasion on which this has been done, the results are here put on record.

The observations are summarised in the table given below.

The ship's course lay from a position due south of Sardinia on the morning of May 12, to the vicinity of Malta on the following morning (see Fig. 1). Although on the former day the ship occasionally passed within a distance of about ten miles from the African coast, the wind always had an off-sea component so that the condition of the air is unlikely to have been affected by the proximity of the land.

The ship was provided with a pressure-tube anemometer at the mast-head, recording on a dial indicator below. The true wind velocity and direction were obtained by compounding vectorially the observed air speed and direction with those of the ship.

The air temperature and humidity were measured at a height of 7.5 m. above the sea by means of an Assmann psychrometer, which was always held over the extreme bows of the ship so that the air reached it without coming into contact with any part of the vessel.

The sea temperature was found by using a canvas bucket and drawing a sample of water from right forward to avoid any possible heating by the ship. All thermometers had been carefully calibrated and the readings shown are the corrected values.

The temperature gradient was measured by a pair of platinum resistance thermometer elements carried at the mast-head and over

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the bows respectively.[1] Each element was mounted in a special housing shown diagrammatically in the sketch (Fig. 2). The element itself is situated inside the central tube of white glazed porcelain of one inch internal diameter. This is surrounded by the bell-mouthed copper cylinder, which, with its cap, is enamelled white. A vigorous inflow of air was maintained over the element by means of a pipe system which runs to a motor pump. The porcelain tube was made to project an inch below the bottom of the copper cylinder, so that the air being sucked in had not come into contact with the outer casing. The two elements were connected in the opposing arms of

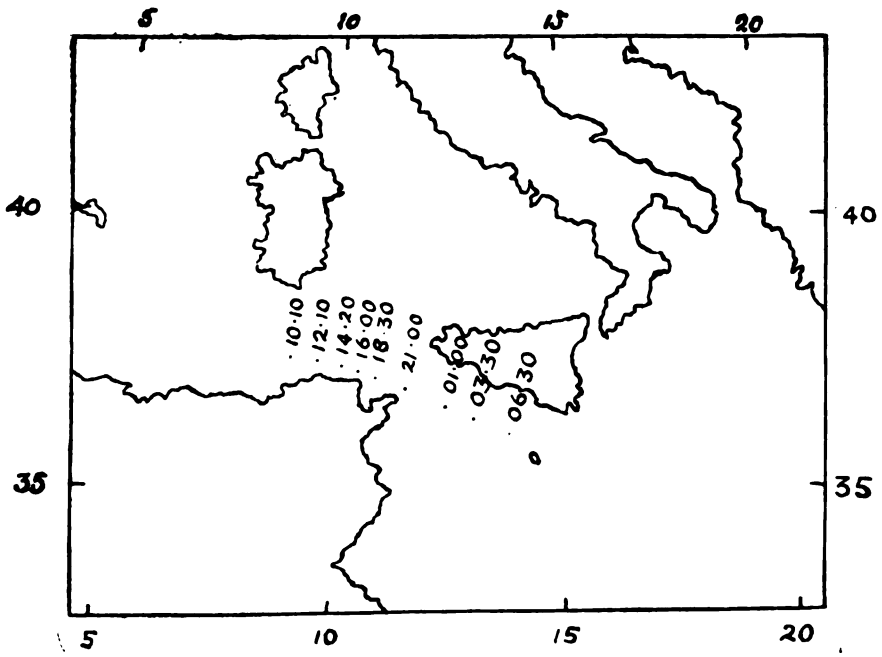

FIG. 1.—Map showing ship's course with places and times of observations.

a Wheatstone bridge circuit, with, of course, compensating leads. A large Einthoven galvanometer was employed for obtaining the balance, a system of shunts enabling the temperature difference of the two elements to be measured easily to within 0°.01C. It is not claimed that the readings represent the actual air temperature with this accuracy, although it is believed that the errors are not very many times this amount.

The measurements of air temperature show a diurnal variation of 1°.05C. with a maximum at 14.30 G.M.T.

The sea temperature shows somewhat irregular variations which are to be attributed to the change of position of the ship. At the same time, the mean of the readings taken during the day, is 0.5°C. higher than the mean of those taken at night. Whether any part

[1] The actual heights above the sea were 22 m. and 5 m.

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of this is a diurnal effect it is not possible to decide, although such a variation does not seem impossible in view of the lightness of the wind and the calmness of the sea.

With regard to the temperature gradient, it is pointed out that the temperature differences shown in the table are all in degrees centigrade. The fact that the dry adiabatic lapse rate is o°.01C. per metre enables the nature of the gradient to be seen at a glance. Thus, the height interval between the elements was 17 m. and the dry adiabatic lapse rate is consequently o°.17C. It will be seen that the temperature gradients observed during the day were almost exactly equal to the dry adiabatic lapse rate, whilst, during the night, values appreciably in excess of this were recorded. This result is in marked contrast with what is found over land. Under

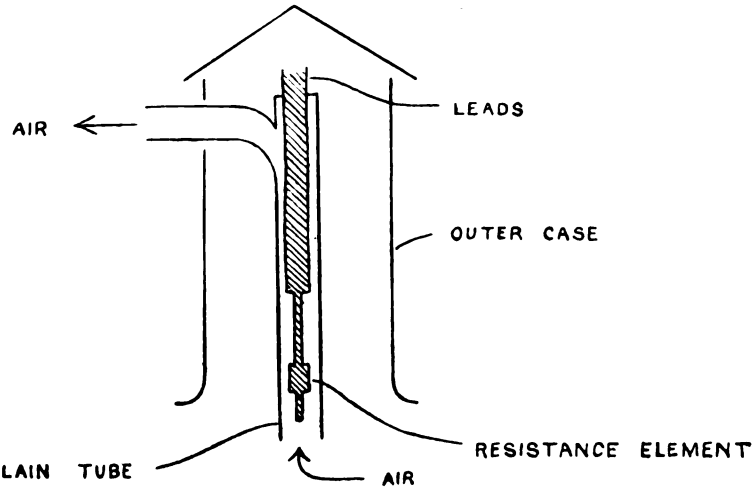

FIG. 2.—Diagram showing the housing of the elements of the platinum resistance thermometer.

similar conditions over land, the day-time lapse over this height interval would certainly have been at least ten times the adiabatic value. On the other hand, an inversion of at least 3°C. would have been obtained over land on a similar night. Thus the diurnal variation of temperature gradient found over land is entirely absent at sea. In fact the results indicate a steeper lapse rate during the night. It is not possible, of course, to say whether this is the normal occurrence at sea, but the following reasoning shows that it is not unlikely to be so. The vertical temperature gradient in the air over the sea is primarily dependent upon the relative temperatures of the sea and the air over the more recent portion of the latter's trajectory. If the sea is colder than the air, we find a temperature inversion. On the other hand, if, as in the present case, the sea is warmer than the air, there will be a decrease of temperature with height. Under most conditions, the temperature of the sea must remain sensibly constant throughout the twenty-

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four hours, whilst the air has a diurnal variation of about 1°C. Thus at night time the air is, relative to the sea, 1°C. colder than during the day. If, during the day, the air temperature does not exceed the sea temperature, there is therefore likely to be a slightly steeper lapse rate at night. But if there is an inversion during the day, the tendency to produce a lapse will be diminished, since the inversion will tend to prevent the upward diffusion of the temperature changes.

In the present series of observations, the variation of sea temperature—possibly with place—renders it difficult to test this reasoning in this particular case. It can only be said that the first four lapses which are small correspond to a smaller mean (sea *minus* air temperature) than the last four which are larger—the first set being day observations and the last set, night observations.

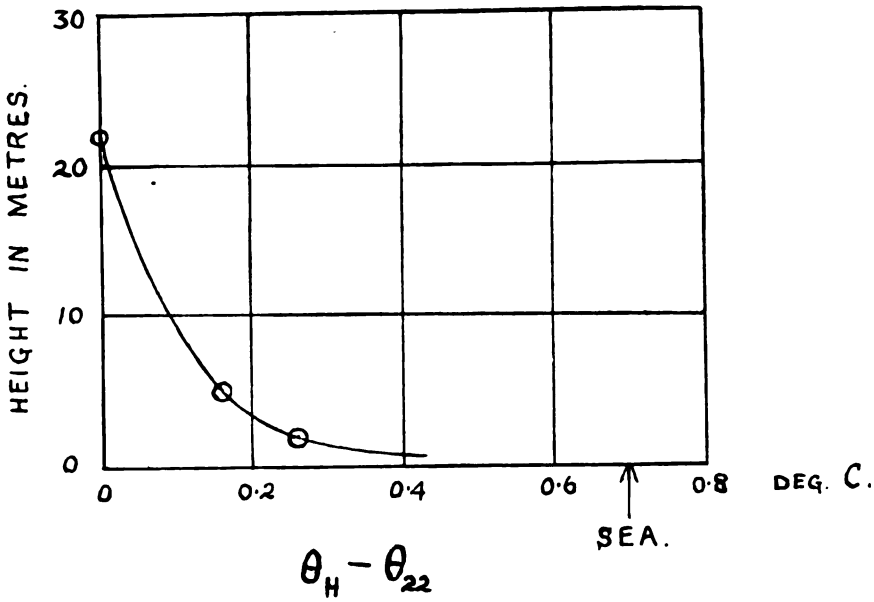

FIG. 3.—Variation in the temperature gradient with height above the sea.

The single observation obtained by lowering the for'ard element to within two metres of the sea, shows that there was a temperature difference of 0°.10C. between heights of 2 m. and 5 m. The gradient thus becomes steeper as the sea is approached.

This is shown in the graph (Fig. 3) in which temperature differences are plotted against height above the sea. The air temperature at a height of 22 m. is taken as the zero of reference, and the temperatures at other heights are plotted as differences from this value. Thus at 5 m. and 2 m. the air temperatures were 0°.16C. and 0°.26C. higher than that at 22 m., whilst the sea was 0°.70C. warmer. The graph shows that there is a super-adiabatic lapse rate near the sea surface, but that the rate has fallen to the adiabatic value at a height of about 10 m.

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TABLE I.—Vertical Temperature Gradients in the First 20 m. Above the Sea in the Mediterranean Sea, May 12, 1926.

Time G.M.T.	Lat. N.	Long. E.	WIND.		Air Temperature.	Relative Humidity.	Sea Temperature.	Temperature Gradient, per 17m.	Sky.
			Velocity.	Direction.					
	° ′	° ′	m./secs.		°C.	%	°C.	°C.	
10.10	37 36	8 57	4.0	41	16.3	—	16.95	−0.16	8/10 Ci.
12.10	37 30	9 29	2.5	4	16.35	—	17.05	−0.16	1/10 Ci.
14.20	37 24	10 01	5.0	17	16.6	—	17.0	−0.15	1/10 Ci.
16.00	37 21	10 25	6.3	27	16.4	—	17.25	−0.16	2/10 Ci.
18.30	37 14	10 56	5.0	37	16.2	87	—	−0.21	4/10 Ci.
21.00	37 04	11 31	1	?	16.2	84	16.5	−0.17	Clear.
01.00	36 43	12 33	4.1	293	15.55	84	16.15	−0.21	Clear.
03.30	36 30	13 09	4.2	310	15.55	84	16.7	−0.27	Clear.
06.30	36 14	13 57	2.8	293	15.8	86	16.95	−0.19	2/10 Fr. St.

At 15.10 $\left(\frac{d\theta}{dz}\right)_{2m.}^{22m.} = -0.26$ °C.

Note.—1. Air Temperature and Relative Humidity were measured at a height of 7.5 m. above the sea.
2. The values of Temperature Gradient are the actual temperature differences between heights of 5 m. and 22 m. above the sea.
3. The negative signs of Temperature Gradient indicate that temperature decreased with increasing height on each occasion.

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DISCUSSION.

Mr. BONACINA remarked that general testimony to the effect that marine cumulus cloud had a well-marked maximum frequency in the early morning, unlike land cumulus which had its greatest frequency in the afternoon, was in keeping with the higher lapse rate of temperature at night shown by Mr. Johnson's observations.

He did not agree with Sir Napier Shaw's comment on the unsuitability of the month of May for exhibiting the observations in question. With powerful sunshine and long days, May was almost as typical of summer as June or July. The cold snaps of May were due to invasions of polar air, such as, in milder form, might occur at any time in summer.

Dr. RICHARDSON gave a brief summary of a co-operative research which will be reported more fully in a later number of the *Journal*.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

October 20, 1926.

An *informal meeting* was arranged on this date in order to welcome Dr. T. Okada, Honorary Member and Symons Medallist, Director of the Central Meteorological Observatory, Tokyo, who was paying a brief visit to England in company with Dr. S. Fujiwhara, of Tokyo.

The PRESIDENT (Sir Gilbert Walker) welcomed Dr. Okada not merely as a representative of a country with which Great Britain had been in alliance and had educational association with, but also as the head of a national weather service, and still more as an Honorary Fellow and a Symons Medallist of the Society. He welcomed also Dr. Fujiwhara, whose contributions to the *Journal* were conspicuous for their boldness of conception.

Dr. OKADA in reply said: Mr. President, Ladies and Gentlemen,—It is a very great honour to us that this evening you have called a special meeting of the Society for our benefit and have given us the pleasure of meeting many of our British colleagues.

In 1924 the Society did me the honour of conferring on me the Symons Medal and in 1925 elected me an Honorary Member. I cannot find adequate words to express my feeling of thanks for the kindness shown to me, not merely from my poor knowledge of English, but also from my feeling of emotion. I should like, however, to tender thanks, Mr. President, for the kind words which you have spoken. Really I don't believe that I properly deserve such honours; any research work in meteorology that I have myself carried out is scarcely worth mention. But if any such exists, it is due, I think, to the fact that I followed the policy of Sir Napier Shaw, former head of the British Meteorological Office, when I invited a number of young physicists and mathematicians to work in our Observatory. They have done something in our beloved science.

Lastly, I take the opportunity of expressing my sincere thanks on behalf of our Observatory for the sympathy and kindness which the Fellows of the Society extended to us in the case of the great catastrophe of 1923. All the books and pamphlets kindly sent by the Society are preserved in the library of our Observatory and will remain for ever as a memorial of your extreme goodwill and generosity.

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A selection of lantern slides, recently presented to the Society by Mr. G. A. Clarke, of Aberdeen Observatory, was shown on the screen, and a paper entitled " Cloud Studies " by Dr. S. Fujiwhara was read by a Secretary.

November 17, 1926.

At the *Ordinary Meeting* the following candidates were balloted for and elected Fellows of the Society:

CHARLES BELLINGER, Winner Street, Paignton;
ROBERT ST. CLAIR BIRD, M.A., c/o Messrs. Dodd, Thomson & Co. Ltd., 63, London Wall, E.C.2;
JOHN WILLIAM DARBYSHIRE, B.A., 42, Elmwood Avenue, Belfast;
NEVILLE ALDRIDGE HOLDAWAY, M.C., B.Sc., La Martinière College, Lucknow, India;
JOHN WILLIAM JOSSELYN, Lieut. R.N., 9, The Boltons, S.W.10;
HARRY STEWART MURRAY SMITH, Lieut. R.N., H.M.S. *Hermes*, c/o G.P.O.;
NORMAN KNIGHT NINESS, 65, Douglas Road, Handsworth, Birmingham;
FLEMING VOLTELIN VAN DER BYL, Bilton Grange School, near Rugby;
WILLIAM FREDERICK VINT, J.P., Cedars End, Sunderland;
VIVIAN JOHN VOELCKER, Lieut-Com. R.N., 7, Durham Villas, W.8; and
FRANK MICHAEL WALTON, Lieut. R.N., Meadow Cottage, Axminster, Devon.

Messrs. Ball, Baker, Ash & Co., Chartered Accountants, were appointed auditors of the Society's accounts for 1926.

December 15, 1926.

At the *Ordinary Meeting* the following candidates were balloted for and elected Fellows of the Society:

PATRICK HUNTER GILLIES, M.O.H., Monzie, Connel, Argyll;
RAFEL PATXOT I JUBERT, F.R.A.S., Passeig Bonanova, 28, Barcelona;
STEPHEN SARGENT VISHER, Ph.D., Indiana University, Bloomington, Indiana, U.S.A.; and
JOHN WILLIAMS, Captain, Lloyd's Agent, Aberdovey.

CORRESPONDENCE AND NOTES.

The Daily Fall of Rain over the British Isles.

The literature on the subject of the rainfall of the British Isles does not contain any statement as to the mean area affected by the rainfall of any day. Nor does there appear to be any generalization as to the frequency of days on which rain was either widespread or experienced at a few stations only. Some attempt to answer these questions has been made by considering the data for 1923. The records from one hundred representative stations were utilized, the selection being made so that the stations were evenly distributed and so that the means of

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the annual totals computed separately for the stations in England, Wales, Scotland and Ireland were close to the computed means for countries given in *British Rainfall*, 1923. In dealing with 100 evenly distributed stations each record may be considered to be representative of one per cent. of the whole area of the British Isles, *i.e.*, of 121 square miles or about the area of the County of London. The daily amounts for these 100 stations were arranged with the falls of each day in one column, so that the relative wetness or dryness of each day could be readily assessed.

In the first place the number of stations experiencing rain (*i.e.*, .01in. or more) were counted for each day and the values for the 365 days in the year classified. Taking the British Isles as a whole, the average number of days on which rain falls is about 210 in the year. Thus, days in which rain falls over more than half the area of these islands are likely to predominate. The table below gives the number of days on which rain fell over specified percentages of the area of the British Isles.

TABLE I.—FREQUENCY OF OCCURRENCE OF DAILY RAIN OVER SPECIFIED PERCENTAGE AREAS OF THE BRITISH ISLES IN 1923.

Percentage of Area of British Isles over which rain fell.	Number of days.	
0—10	10	
11—20	16	
21—30	21	122
31—40	38	
41—50	37	
51—60	33	
61—70	48	
71—80	37	243
81—90	51	
91—100	74	
0—100	365	

Table I. shows that during 1923 rain fell on more than half the total area of the British Isles on 243 days, and on half or less than half the area on 122 days only. Rain fell at each of the 100 stations on seven days, at 99 stations on nine days, at 98 stations on eight days, and at 97 stations on six days.

The seven days with rain at every station were January 1 and 2, April 10, May 10 and 15, October 12 and November 13. The rain of January 1 and 2 was associated with the approach to these islands of a deep depression, and that of May 10 with a depression off the north of Scotland. In the remaining four cases the rain was associated with the passage of secondaries across these islands. On the other hand rain fell at less than ten out of the 100 stations on only nine days, and at less than five stations on four days, viz., March 17, 18 and 19, and June 28, when the numbers of stations with rain were one, two, one and two respectively. There was thus not a single day that was rainless at all the 100 selected stations. On all four days the British Isles were under the influence of an anticyclone and there was a marked divergence of the isobars. During

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the period March 17-19 the high pressure was centred to the north-east, and east to south-east winds prevailed. On June 28 the high pressure was centred to the west of Ireland and winds were northerly.

Another aspect of the question is the *quantity* of rain deposited in one day. The means of the daily amounts at the 100 stations, *i.e.*, for January, 1, 2, etc., were computed for each day and classified according to their magnitude. Table II. shows the frequency of occurrence of values within specified limits. It should be mentioned that the year 1923 was a fairly wet year, the figure for the whole country given in *British Rainfall* being 114 per cent. of the average of the 35 years 1881-1915. The normal daily fall for the British Isles for this period is 0.113in.

TABLE II.—FREQUENCY OF OCCURRENCE OF GENERAL DAILY RAINS OVER THE BRITISH ISLES IN 1923 IN SPECIFIED LIMITS.

General Daily Fall over British Isles.	Number of days.	
0.000—0.049	112	186
0.050—0.099	74	
0.100—0.149	66	179
0.150—0.199	37	
0.200—0.249	21	
0.250—0.299	24	
0.300—0.349	16	
0.350—0.399	7	
0.400—0.449	3	
0.450—0.499	4	
0.500—0.549	0	
0.550—0.599	1	
0.000—0.599	365	

It appears that during 1923 the general fall over the whole British Isles was less than 0.1in. on 186 days and as much as or more than this amount on 179 days, *i.e.*, on about an equal number of occasions. The four days March 16 to 19 were conspicuous with a total general fall of less than 0.01in. August 29 stands out with the largest general fall of 0.57in. On that day, rain fell at 99 of the stations. A general fall of 0.01in. over the British Isles is equivalent to 78,000,000 tons of water, and therefore the mass of water deposited on August 29 amounted to the huge quantity of four and a half thousand million tons.

It is interesting to note that the days of heavy rain selected by the method here described are not those selected for individual discussion in *British Rainfall*. In these volumes the days considered in detail are those in which falls of 2.5in. or 7.5 per cent. of the annual amount are recorded at individual stations. Of the thirty days with rain at 97 or more of the selected stations in 1923, only nine had falls of this amount and then, in most cases, at only one station. It is clear, therefore, that the days of heavy individual falls are not often those in which the rain over the British Isles as a whole is either most widespread or most significant. This encourages the continuation of the study of daily falls from this aspect and especially in relation to the types of pressure distribution as shown by the maps in the daily weather reports.

J. GLASSPOOLE.

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Non-Linear Relations with Sunspots.

As is well known, direct correlation between sunspots and meteorological phenomena usually gives small and unconvincing coefficients. Two hypotheses may be advanced in explanation of this regrettable fact: either the relationship itself is not close, or it is not linear. The first hypothesis is the one which is generally adopted, and in the majority of instances it is undoubtedly correct, but the second is not entirely excluded and is worthy of examination.

The classical example of a terrestrial phenomenon which shows a relationship to sunspots is tropical temperature. The figures given by W. Köppen[1] for the variations of mean annual temperature over the tropical zone in general were accordingly classified according to the corresponding mean annual sunspot number, with the result shown in Table I. and Fig. 1.

TABLE I.—Relations of tropical temperature to sunspot numbers.

Sunspots, Limits .	0–5	6–10	11–20	21–30	31–50	51–70	71–100	>100
,, Mean No.	3	7	14	25	41	61	84	120
Mean temp. . .	+3.2	+2.6	−0.3	+0.5	−0.1	−0.7	−1.9	−2.9
Number of obs. .	6	10	12	10	20	24	11	7

There is some irregularity in the distribution of the crosses with sunspot numbers between 10 and 30, but the general trend of the figures shown by the smoothed full curve is unmistakable—the curve rises far more rapidly in the region of the lower sunspot numbers than in that

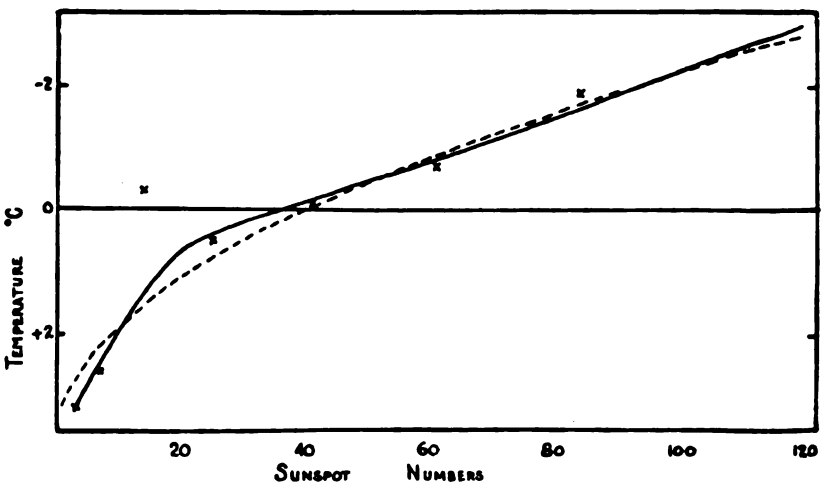

Fig. 1.—Relation between Sunspot Numbers and Tropical Temperature (variation from annual mean).

of the higher numbers. (Note that in Fig. 1 the scale of temperature is

[1] Lufttemperaturen, Sonnenflecke und Vulkanausbruche, *Met. Zs.*, 31, 1914, p. 305.

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reversed.) The relationship is definitely non-linear. The significance of the broken curve will be referred to later.

This result may be checked by comparison with a few other meteorological series which have a high correlation with sunspots. First we may take the levels of Lake Victoria in Central Africa[2] (Table II.)

TABLE II.—Levels of Lake Victoria and sunspot numbers.

Sunspots, Limits . . .	0–10	11–30	31–50	>50
„ Mean No. . .	5	21	44	69
Mean level	−5.1	4.4	8.1	21.4
Number of Observations	8	8	7	7

which have a correlation with sunspots of +0.8. Data are available for only thirty years and it was necessary to take rather large sunspot divisions; the plotted figures do not show clearly whether the relation is best expressed by a straight or a curved line.

The number of thunderstorms in Central Siberia has recently been shown to have a close relationship with the sunspot number.[3] The corre-

TABLE III.—Siberian thunderstorms and sunspot numbers.

Sunspots, Limits . . .	0–5	6–10	11–20	21–30	31–50	51–70	>70
„ Mean No. . .	3	7	15	26	43	61	84
No. of Thunderstorms .	9.7	10.9	12.7	14.0	15.6	17.7	18.2
No. of Observations . .	4	7	4	4	7	6	5

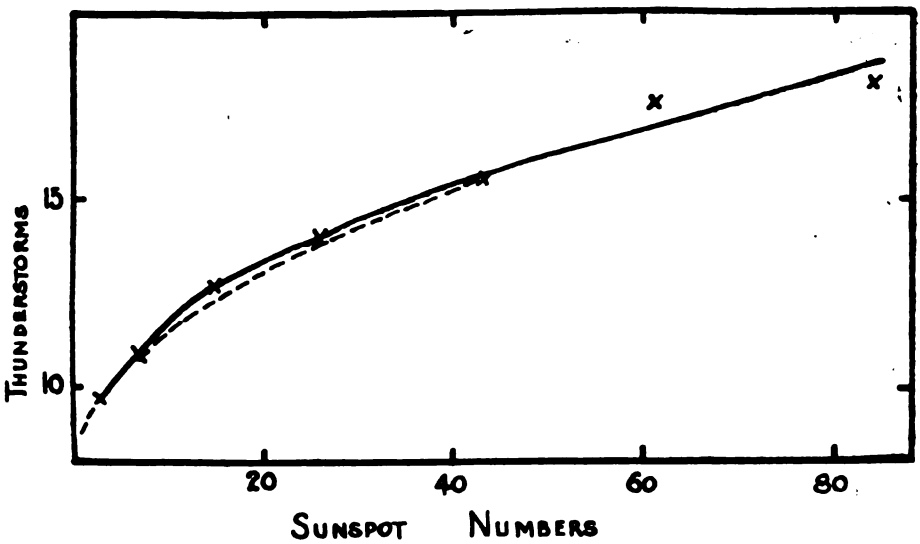

Fig. 2.—Relation between Sunspot Numbers and Thunderstorms in Central Siberia.

[2] London, Air Ministry, Meteorological Office. *Geophysical Memoirs*, No. 20, 1923. The data were extended to 1925.

[3] Septer, E. Sonnenflecken und Gwitter in Siberien. *Met. Zs.*, 43, 1926, p. 229. See also *Meteorological Magazine*, 61, 1926, p. 216.

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lation coefficient is as high as +0.88. The data are set out in Table III. and Fig. 2. Here the non-linear nature of the relationship is very clearly shown.

Finally we have the annual rainfall at Bathurst (Gambia). The data are shown in Table IV.; apart from a slight irregularity with sunspots

TABLE IV.—BATHURST RAINFALL AND SUNSPOT NUMBERS.

Sunspots, Limits . . .	0–5	6–10	11–30	31–50	51–70	<70
,, Mean No. . . .	3	7.5	21	43	61	84
Mean Rainfall (ins.) . . .	33.3	42.7	49.7	48.5	50.9	55.4
No. of observations . . .	4	6	7	6	7	5

between 30 and 50, the non-linear relationship is very clear. Thus three out of four instances show that the effect of an increase of the relative sunspot number from 0 to 10 on meteorological phenomena is much greater than the effect of an increase from, say, 70 to 80.

At this point it is necessary to consider exactly what the sunspot number represents. It is taken as a measure of solar activity. For terrestrial purposes the important part of solar activity is the radiation of energy, but the amount of energy radiated is not necessarily proportional to the sunspot number. A. Ångstrom[4] found that the daily values of the solar constant obtained at Mount Wilson from 1915 to 1918 can be expressed by the formula

$$C = 1.903 + .011\sqrt{S} - .0006\,S$$

This formula gives a maximum value of the solar constant C with a relative sunspot number S of 85, but the plotted observations show an ill-defined maximum of C with values of S between 100 and 160. As a first approximation we may leave out the final term and represent the curves in Figs. 1 and 2 by expressions of the form

$$M = a + b\sqrt{S}$$

where M represents the values of the meteorological elements considered. For tropical temperature (deviation from normal) we obtain by the method of least squares :—

$$T = 3.8 - 0.6\sqrt{S}$$

and for the frequency F of Siberian thunderstorms

$$F = 7.6 + 1.2\sqrt{S}$$

These equations are represented by the broken curves in the figures. For the thunderstorms the fit of this theoretical curve is very good; for the tropical temperatures the $\sqrt{S}$ curve is too low for values of S between 12 and 50, but the fit is good for other parts of the curve. For both curves the fit would be improved by the addition of a very small S component of opposite sign to that for $\sqrt{S}$. For the thunderstorms the actual equation is :—

$$F = 7.2 + 1.36\sqrt{S} - .012\,S$$

The moral of all this is that when correlating a meteorological element with sunspots, a sliding scale should be employed instead of the actual sunspot numbers. For practical purposes the $\sqrt{S}$ relation appears to be

[4] Solar constant, sunspots and solar activity. *Chicago, Astrophys. Journal*, 55, 1922, p. 24.

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sufficiently accurate, and a suitable scale of values is shown in Table V. It will be noticed that all the sunspot numbers higher than 95 are given the same scale number of 20; this is to allow for the flattening of the curves in the region of the higher sunspot numbers owing to the introduction of the term S with a negative coefficient.

TABLE V.—Scale for Correlation with $\sqrt{S}$.

Sunspot Nos.	$2\sqrt{S}$.	Sunspot Nos.	$2\sqrt{S}$.	Sunspot Nos.	$2\sqrt{S}$.
0.0	0	11–14	7	46–52	14
0.1–0.5	1	15–18	8	53–60	15
0.6–1.5	2	19–22	9	61–68	16
1.6–3	3	23–27	10	69–76	17
4–5	4	28–33	11	77–85	18
6–7	5	34–39	12	86–95	19
8–10	6	40–45	13	>95	20

As an example of the improvement effected by substituting $\sqrt{S}$ as a variant for S, the correlation coefficient between Siberian thunderstorms and the sunspot values given by the scale in Table V. becomes +0.92 instead of the figure +0.88 obtained by direct correlation with the sunspot numbers.

C. E. P. Brooks.

Periods of Constant Temperature.

M. Albert Baldit in the July number of *Comptes Rendus* (**183**, 1926, pp. 139-141) has examined the temperature records of the meteorological station Puy-en-Velay, situated at a height of 684 m., for the period 1910-1925, and from them collected the occasions when a period of twelve hours was marked by a variation of temperature less than 1°C. The mean temperature, amplitude of oscillation, the time of commencement, and the duration of each period was noted. From the sixteen years examined, a total of 301 cases was found, which, divided among the months, shows a decided annual variation. January, the time of maximum frequency, has 65 cases, November and December occupying the second and third places with 56 and 48 cases respectively, while the number per month sinks to zero during July. In each month the temperature at which such periods are most frequent is in the neighbourhood of the monthly mean, but is generally a little above this value by an amount which is greater for months of greater diurnal variation.

The temperatures at which the periods occur most frequently are −4°C., 6°C. and 13°C. The reasons for the first value (−4°C.) are the same as those which give 0°C., the greatest frequency at mean sea level. A saturated layer of air at freezing point at sea level lifted to a height of 684 m. would arrive with a temperature −4°.3C. If the air were not saturated the temperature would be lower by an amount depending on the degree of moisture present. The maximum frequencies at 6°C. and 13°C. M. Baldit ascribes to the two predominating wind currents, from W and from S.

The period of the day during which temperature is most frequently constant is that from 11h. to 23h., and the period with constant tem-

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perature least frequent from 23h. to 11h. (274 to 31). The maximum frequency occurs between 17h. and 18h. with a slight variation with the time of sunset. A secondary maximum occurs between 12h. and 13h., very clearly marked and which is ascribed as being connected with the maximum cloudiness which occurs at the same time.

Classified according to wind direction, he finds that of the total (301), 89 occur with NW winds, 53 with N winds, and 55 with NE winds. E, SE, SW and W together produce only 24 cases, while S winds are responsible for 34 occasions. The northerly winds (NW to NE) correspond to the low temperatures of winter with overcast skies.

Abstract.

Cloud Photographs.

We are indebted to the Director of the Meteorological Office, London, for permission to publish some photographs of clouds taken in Egypt and Palestine in recent years. The particulars accompanying the individual cloud studies are meagre, but the following supplementary details from synoptic charts may prove interesting.

1. ALTO-CUMULUS.

This photograph, taken at Helwan on January 29, 1924, shows a layer of alto-cumulus with a decided billow formation. The cloud was estimated to be at a height of 12,000ft., the camera being pointed to the south. The winds from 2 km. to 4 km. were from the west, a low centred over the Mediterranean maintaining a westerly wind gradient. Below this alto-cumulus sheet which on the left is more like high strato-cumulus is a layer of fracto-cumulus. The river below is the Nile, with the cultivated areas showing as darkened strips on either bank.

2. STRATO-CUMULUS.

Fig. 2, taken from a height of 7,000ft. at Helwan, shows the upper surface of a bank of strato-cumulus. The photograph was taken at 05.30 (G.M.T.) on November 3, 1924. The cloud was at a height of 5,000ft. Surface winds were from SE and from NW at 2 km. There had been no rain in the previous 24 hours.

3. CUMULO-NIMBUS.

This picture taken at Ramleh shows a well-defined anvil cloud formation over a rocky desert scene. Northerly winds prevailed over Palestine and Egypt at the time (June 7, 1924), pressure being lowest over Baghdad and Mosul, while an anticyclone covered Switzerland and northern Italy.

4. CIRRO-CUMULUS.

Fig. 4 depicts cirro-cumulus seen through the gaps in cumulus cloud at a lower level. The ripples in the original are very well defined. The photograph was taken at Ramleh (February 2, 1924) at a time when pressure was highest over Irak, a low over the Mediterranean giving strong westerly winds up to 4 km. over Egypt.

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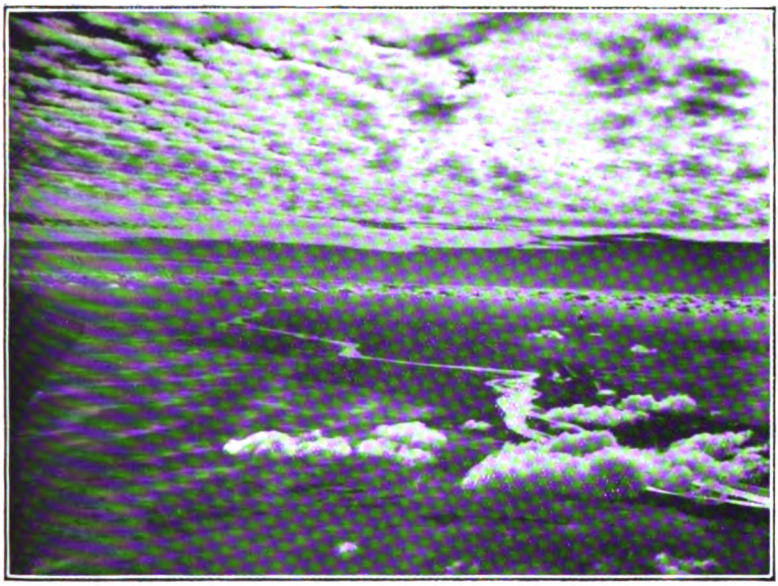

FIG. 1.— Alto-cumulus over the Nile.

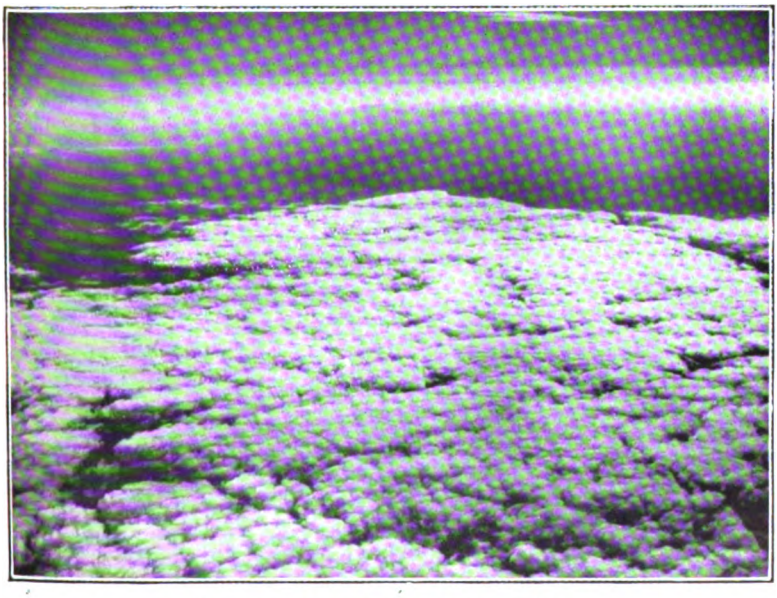

FIG. 2.—Strato-cumulus, upper surface.

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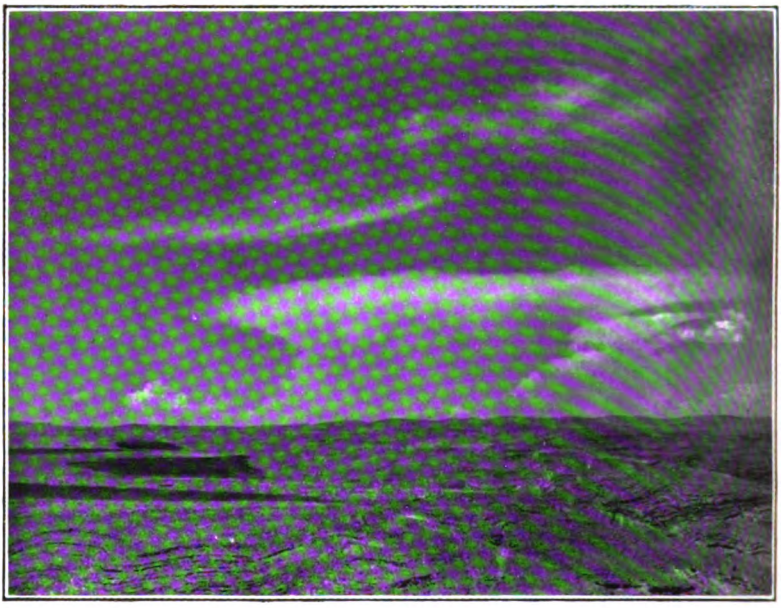

FIG. 3.—Cumulo-nimbus.

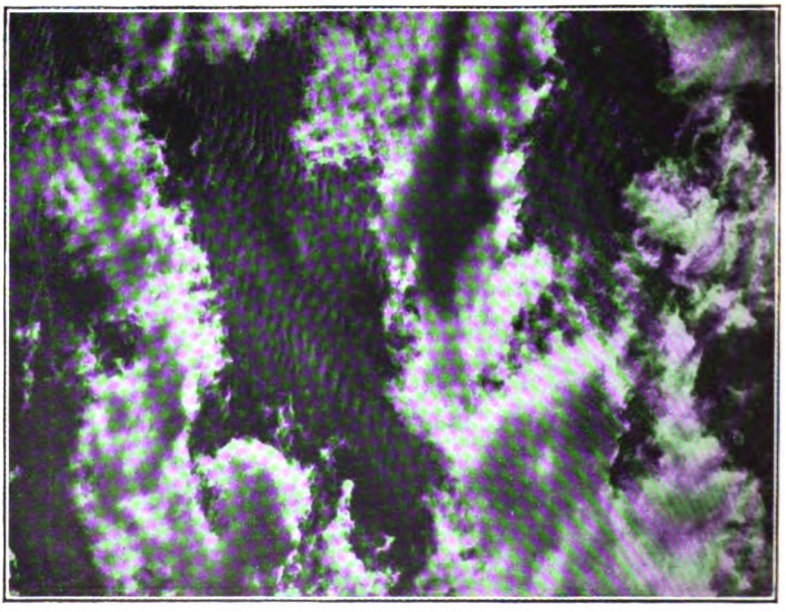

FIG. 4.—Cirro-cumulus.

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Vladimir Köppen.

We offer our sincere though somewhat belated congratulations to our senior Honorary Member, Professor Vladimir Köppen, on the occasion of his eightieth birthday, which occurred on September 25 of last year. Meteorologists of all countries have joined in sending Professor Köppen their congratulations coupled with the wish that he may be spared for many years to come to continue his work in the service of meteorology. The *Deutsche Seewarte*, on the staff of which Köppen served with distinction for no fewer than 44 years, 1875-1919, in September last published in his honour a special number of the *Annalen der Hydrographie und Maritimen Meteorologie* containing papers by eminent meteorologists of all countries—a form of honour which will have been particularly acceptable to one who throughout his long life has made the development of his science his main concern. Some idea of the extraordinary intensity of Köppen's activity may be gathered by a glance through the list of papers from his pen published during the last ten years. The list, which occupies no less than two closely-printed pages in the mere enumeration of titles, brings up to date a similar list published in the *Annalen* in 1916. The September number of the *Meteorologische Zeitschrift* also contained a number of special articles in Köppen's honour, one of which by our Honorary Member, Professor Hergesell, dealing with the development of Aerology, is reproduced below.

The Development of Aerology.[1] A Retrospect and a Glance into the Future. By H. Hergesell, Director of the Aerological Observatory at Lindenberg.

Our era is one of rapid change and development, particularly in the domain of science and its applications. It is well, therefore, to pause occasionally to review progress, particularly as there is sometimes a tendency to treat as entirely new, problems that have in fact a considerable history behind them. My object in writing this note is both to remind us of the past and to stimulate new endeavour, and I undertake the task with the more pleasure as it affords me the opportunity of doing honour to the distinguished scientist, Vladimir Köppen, whose eightieth birthday is specially commemorated in this volume.

The need for meteorology to get away from surface conditions and push its observations into the free atmosphere became generally recognized during the 'eighties of last century. The fact that an interest in aviation was developing about the same time considerably helped the new line of research. Proposals for the construction of dirigible airships attracted much attention, though the practical results achieved may have been small. Aeronautical societies were founded in many towns in Germany, Berlin, Munich, Strassburg. Their members soon turned from the impracticable idea of dirigible airships and devoted themselves to the sport of free ballooning, which, under the guidance of scientific men, led directly to the meteorological investigation of the free atmosphere. Special mention should be made of the activities of the Berlin Society, which, under the guidance of Assmann, and adequately supported financially from public funds, achieved those remarkable results which are contained for us in three handsome volumes. I need not go into details. In addition to Assmann, I will only mention Berson, Süring

[1] Translated from the *Meteorologische Zeitschrift*, September, 1926.

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and Gross of the Berlin Society, Erk, Sohncke, Emden, von Bassus in Munich and Moedebeck and the present writer in Strassburg, all of whom took an active part in the investigation of the atmosphere with manned balloons.

Captive balloons were also being pressed into the service of our science. The observations in the lower layers of the atmosphere made with the Berlin balloon *Meteor* and with the Strassburg balloons are well known. Important as the results obtained with manned balloons were, it soon became obvious that this method of research could only be used occasionally. It was too costly and cumbersome for regular use. The search for other and simpler methods was actively prosecuted in many quarters. In the West, in France, Teisserenc de Bort founded a dynamical observatory at Trappes during the 'nineties and made it a centre for regular kite ascents. He also devoted much of his energy to developing another method first suggested by two of his compatriots, Hermite and Besançon, viz., the method of using unmanned so-called sounding balloons for raising recording instruments to great heights in the atmosphere. Working with paper balloons of the prodigious size of 100 m.^{3} he succeeded in lifting recording instruments to a height of 15 km. This line of investigation was adopted also in Germany. The German balloons were made of varnished silk or cotton fabric coated with indiarubber, and like the French balloons, had to be of considerable size if heights of more than 10 km. were to be reached. Ascents of sounding balloons were in those early days both expensive and difficult. Open balloons had an additional drawback in that their ascensional velocity decreased rapidly with increasing altitude, so that the ventilation of the recording instruments became small. For that reason the existence of the stratosphere which these ascents seemed to demonstrate was challenged by many, as the observed increase of temperature with height was attributed to radiation, solar or terrestrial. Teisserenc de Bort attempted to convince the doubters by sending up his balloons at night, and succeeded in placing beyond doubt the existence at night of the upper temperature inversion. The controversy over the stratosphere was, however, not finally disposed of until the introduction of closed rubber balloons by Assmann furnished overwhelming evidence of its reality. By close co-operation with the Continental Indiarubber Company of Hanover, Assmann succeeded in obtaining rubber balloons of considerable size and of such excellent quality that they could reach heights of more than 20 km. without bursting and without loss of gas. Closed balloons of this kind had the additional advantage that their ascensional velocity did not decrease with height, but actually tended to increase, so that adequate ventilation of the thermometers was assured even at the maximum height reached. With these balloons the permanent presence of the stratosphere was demonstrated by ascents made in full sunshine and it became possible to extend the investigation to heights till then regarded as unattainable. Nowadays balloons have reached 30 km. under conditions of adequate ventilation. The existence of an upper approximately isothermal layer up to this level has been demonstrated beyond cavil, and probably a slight normal increase of temperature from 11 km. upwards may also be regarded as proved, though I do not yet regard the evidence for the latter as complete.

The further investigation and explanation of this entirely new phenomenon of our atmosphere have occupied the attention of physicists and meteorologists in more recent years. Here, as in other fields, we

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find Köppen among the pioneers. The first objective was to acquire further knowledge of the facts of the phenomenon. For that, international co-operation was essential. In 1896 the international organization represented by the quinquennial Conference of Directors and its Permanent Committee nominated an International Commission for the Investigation of the Upper Air, of which I became President. Among German scientists, Köppen, Assmann and Berson were original members and took an active part in the work and meetings of the Commission. Simultaneous ascents of free manned balloons, kites and registering balloons were organized, and it became possible to take in hand the investigation of the extent and distribution of the stratosphere over the globe. This work belongs to the first decade of the present century. The writer of this note succeeded in 1904 in organizing an expedition for the exploration of the upper air over the Atlantic Ocean. We meteorologists owe a lasting debt in this connection to the late Prince Albert of Monaco, who placed his yacht at my disposal for this purpose. In the autumn of 1904 the conditions in the trade wind region around the Canary Islands were investigated by means of kite ascents carried out on board the yacht. The main facts of the vertical distribution were demonstrated. Experience gained on this cruise convinced me that registering balloon ascents at sea were entirely practicable. In the spring of 1905 the earliest ascents of this kind were made in the Mediterranean. Five ascents which reached 9,000 m. demonstrated the practicability of the method both as regards recovery of the instruments and the possibility of reaching the desired height. In August, 1905, the Atlantic atmosphere was explored up to great heights on cruises which extended westward to the Saragossa Sea. The stratosphere was found in lat. 29° 17′ N., long. 21° 50′ W., at a height of 12,900 m. The temperature at the tropopause was 205a (−68°C.). I have described the technique of such ascents elsewhere, but will briefly recapitulate it here. In place of a single rubber balloon, two balloons connected by a long cord are used. The recording instrument is attached at the end of the cord, and below it there is a float at the end of another long cord. Weight and free lift are adjusted to give the whole system an ascensional velocity of about 5 m/s. so long as both balloons are intact. Observations of altitude and azimuth are made with sextant and azimuth-compass from the deck of the pursuing vessel at intervals of, say, one minute. As the ascensional velocity is known approximately the track of the balloon can be computed, due allowance being made for the motion of the ship, and its projection can be plotted on a chart. The balloons continue to rise until one of them bursts. The place of burst and its projection are calculated as closely as possible. The unburst balloon is now no longer able to support the system, which begins to fall with a velocity which is also known approximately. The observations of position should be continued as long as the conditions of visibility permit, but it does not matter very much if the balloon is lost to view. Assuming that the wind distribution does not change materially during the comparatively brief duration of the ascent, the place of fall can be determined by calculation with considerable accuracy as the horizontal projection of the curve of fall is approximately the reflection of that of the curve of ascent. Another way of putting it is that place of ascent, place of burst and place of descent must lie on a straight line on the chart. As soon as the float touches the surface of the sea the unbroken balloon is able to support itself and the instrument above the water and forms an aerial

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buoy which can be easily picked up by the pursuing ship. Allowance for drift can be easily made in computing the position of fall. Immersion of the instrument in the sea is of no consequence if the surface on which the record is made is coated with a thin layer of oil before being smoked. This method, which I myself worked out, was used as early as July, 1905, and a description of it was published. I have used it successfully on later expeditions, and it has been used also on German surveying ships. It is being followed at the present time by a German expedition engaged in meteorological soundings in the South Atlantic Ocean, and I have no doubt it will prove serviceable there also.

Encouraged by the satisfactory results obtained on the Prince of Monaco's yacht, Teisserenc de Bort and A. L. Rotch in 1906 equipped a small steam vessel for aerological observations and sent her under the scientific direction of Clayton and Maurice to investigate the North Atlantic trade wind further south. In these ascents also the stratosphere was identified, using the tandem system which I have just described. A further increase in its height towards the equator was noted. Our ideas about the vertical extension of the trade wind may now be regarded as cleared up in the main. The slight vertical thickness of the trade wind itself, which I first found, has been confirmed. Above the trade wind there is an intermediate transitional layer of relatively great thickness to which the name *Urpassat* has been given by German writers, and above that again the so-called anti-trade.

The development of pilot ballooning was proceeding rapidly at the same time as that of the registering balloon. The introduction of rubber balloons having an approximately constant ascensional velocity made this method of research practicable both by land and at sea. For work on land a suitable form of theodolite was designed by A. de Quervain. The instrument was modified by various other workers, but to this day de Quervain's apparatus as constructed by the firm of Bosch may be regarded as the standard instrument. At sea, pilot balloons were followed with sextant and azimuth-compass. I myself used this method successfully as early as 1904, so that in 1906 I felt justified in recommending it for adoption on merchant ships. After the war, A. Wegener and Kuhlbrodt introduced a special instrument for the purpose.

In 1906 Prince Albert's yacht was cruising in Arctic waters and I availed myself of the opportunity offered for aerological work in high northern latitudes. Numerous ascents of kites, kite balloons and pilot balloons were made near Spitzbergen. Registering balloon ascents were also attempted in spite of the difficulties imposed by fog, strong wind and low cloud. In 1906 one ascent only reached to 8,000 m. and the identification of the stratosphere remained doubtful. A second series of ascents in Arctic waters was undertaken in 1907. I resumed these studies in 1910 on board the *Mainz* in the company of Count Zeppelin. In the course of that summer we succeeded in sending a registering balloon to a height of 13,000 m. The stratosphere was definitely entered at the high level of 12,000 m., which is practically the same as the level commonly encountered over Central Europe. The anticipation, based on observations by Teisserenc de Bort in the North of Sweden, that the stratosphere would be encountered at very low levels in high northern latitudes was thus not confirmed by this summer ascent. In 1908 the training ship *Viktoria Luise* was placed at my disposal by the German Admiralty, and registering balloon ascents were again made off the

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west coast of Africa near the Canary Islands. The work at sea was supplemented by observations at land stations carried out at Teneriffe by Drs. Wenger and Stoll, who were at the time working under me. This expedition gave a particularly good picture of the vertical distribution in the trade wind. In 1909 the work was resumed by a German training ship (Captain Mauwe). On that occasion the trade wind of the western Atlantic was examined. As anticipated, the stratosphere in these low latitudes (15° 45′ N., 67° 21′ W.) was encountered at a great height, 17 km., with a temperature 192a (−81°C.). The vertical distribution under the influence of the South American Continent was materially different from that found in the East. The trade wind extended much higher, up to 6,000 m., while the anti-trade was not entered until very great altitudes were reached. This result was not unexpected.

In 1908 funds had been allocated to Lindenberg Observatory for the equipment of an aerological expedition to German East Africa. Its programme included the intensive exploration with kites and registering balloons of the upper air over Victoria Nyanza, and the enterprise was carried to a successful conclusion under the leadership of Berson and Elias. Here also the stratosphere was not entered until the very considerable height of 17,800 m. was reached. A very interesting wind distribution was observed over this part of Central Africa. The great height of the base of the stratosphere over the equator and the very low temperatures prevailing in it were confirmed during the following years by ascents carried out by the Netherlands Institute at Batavia under the direction of van Bemmelen and later of Braak. There can be no doubt that the height of the base of the stratosphere increases considerably to the southward and that its average height over the equator is greater by some 7 km. than in our latitudes. The low equatorial temperatures at high levels have been used in recent years by Schmauss and others to explain weather changes in our latitudes.

In North America, Rotch arranged for a large number of registering ascents, and such ascents now form a regular part of the work of the State Meteorological Service. Canada also took an active part in the years preceding the outbreak of the war. In Europe there was active co-operation. I may mention specially Russia (Rykatcheff, Kousnetzoff); England (Shaw, Dines); Austria (Exner, Ficker, Wagner); Italy (Palazzo, Gamba); and lastly also Spain, where Galbis took a particularly active part. In Germany all meteorologists of standing have assisted. In connection with registering balloons I mention specially Schmauss as well as Assmann.

Lastly, I come to Köppen. A glance down the list of titles of his papers will give some idea of the many new ideas which Köppen has contributed to the study of the atmosphere. We owe it to him that the *Seewarte* was induced to arrange for pilot balloon work at sea. Encouraged by the success of my pilot balloon ascents in the Antilles and of the *Freya* expedition to the same region under Dr. Jonas, Köppen arranged for the issue of pilot balloon equipment and instructions to the North German Lloyd liner *Halle*, and thanks to the active co-operation of the ship's officers a series of valuable observations was secured from the Atlantic. Similar observations from the liners *Herzogin Cäciliė* and *Herzogin Sophie Charlotte* followed. Thus mainly at Köppen's instigation, wind measurements were collected from all oceans and subsequently published by him.

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In this retrospect I must confine myself to the more important phases of development, and I turn now to the subject of kite ascents. The idea of using kites for the scientific investigation of our atmosphere is an old one. Franklin used them in researches on atmospheric electricity. I believe that Rotch was the first to use them for purely meteorological research. At his own expense he set up a kite station at Blue Hill Observatory near Boston, and on his frequent visits to Europe he managed to interest his scientific friends in work of this kind. Among the number may be reckoned Assmann, Köppen, and the writer. I do not propose here to give the history of Lindenberg Observatory, but I would like to give some particulars of the sister institution near Hamburg which owes its origin mainly to Köppen's initiative. The kite station at Gross-Borstel, near Hamburg, has become famous through Köppen's individual efforts. The eminent savant proved himself to be also a brilliant experimenter. The first serviceable hand-winch was designed by Köppen. The motor-winch, thanks to the development of motors, has now largely displaced it, but the Köppen winch was indispensable to the development of work with kites. Köppen winches were used in the early ascents made at sea; for example, in those made on the *Sleipner* and other German destroyers. Köppen has contributed also to the development of the motor-winch. Anyone contemplating aerological work at sea naturally turned to Köppen for assistance and advice. The great scientist would delight in spending hours in the discussion of methods of splicing wire cables or attaching instruments and similar technical details. The construction of kites was to him an endless source of interest and joy. In the neighbourhood of a large town like Hamburg the breaking away of kites is a source of much trouble, and Köppen endeavoured to mitigate the evil by designing kites which would adapt themselves to variations of wind. His efforts in that direction were particularly successful. The years during which Lindenberg and Gross-Borstel co-operated are the classical period in the development of the technique of kite flying. The fact that Gross-Borstel had ultimately to be dismantled cannot be attributed to any slackening of effort on Köppen's part. It was inevitable owing to the location of the station on the outskirts of a large and growing town and to other causes, not least the retirement of Köppen from the service.

I must return now to the activities of the International Commission. Meetings were held biennially. The place of meeting varied: Strassburg, Paris, Berlin, St. Petersburg, Milan, Monaco, Vienna, were visited in turn. The meeting at St. Petersburg was of special importance, for at it funds were collected which enabled the President of the Commission to publish the results of the international ascents in collective form. Köppen attended most of the meetings and took an active part in the discussions. Things got particularly interesting when two men like Köppen and Bjerknes joined issue. Köppen it was who got moving the question of the introduction of millibars, and perhaps we owe to him the decision which was ultimately taken. All who took part in the memorable meeting at Vienna will remember the highly interesting discussion in which, among others, Trabert, still in full vigour, took such active part. At Milan Köppen suggested the now generally recognized name "Aerology" for our particular branch of meteorological science.

The development of aerology became ever more dependent on international co-operation. From 1912 onwards many proposals which

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ultimately led to new expeditions originated in the Commission. Aerological polar study was fostered by the nomination of a special Sub-Commission. At a meeting held in Copenhagen shortly before the war, plans were worked out for the establishment of a network of aerological stations surrounding the pole. The establishment of permanent stations for aerological research in German East Africa was projected. In co-operation with Count Zeppelin an airship cruise to the Arctic regions was in preparation on which registering balloon ascents by the tandem method conducted either from the ice or from the upper platform of the airship would have played an important part.

Then came the war and the great international enterprise collapsed; all our plans came to nothing. Now, after an interval of years, we are at last in a position to resume. The International Meteorological Committee has been re-established, and with it the International Commission for the Investigation of the Upper Air. But the work that lies before us will be difficult and many obstacles will have to be surmounted. All European countries are impoverished and it is no longer possible to carry out the old plans. A glance forward to explore the possibilities may be all the more useful. I am no pessimist. What contribution can German aerology make to the investigation of the upper air?

Many kite stations were established during the war both inland and on the German coast, and also in occupied territory in Russia and even in Asia. They have all been dismantled, but the valuable observations have for the most part been salved from the wreck and are being discussed. The observations from Turkey have already been published, thanks to Weickmann's efforts. The aim which Assmann and I, as his successor in the directorship of the Lindenberg Observatory, set before ourselves of arranging for regular observations of upper currents over a wide area and for the rapid dissemination of the reports, has been to a large extent realized. A network of aerological stations has been added to the old climatological network to safeguard aviators over German territory by supplying them with information of actual conditions and warnings of anticipated changes. The Ministry of Transport has allocated ample funds to this new service, whose headquarters are at Lindenberg. I need not go into details as the organization is well known to meteorologists and aviators. Naturally an organization of this kind calls for constant extension and improvement, and I should like to refer briefly to a few points which appear to me to be fundamental. The accepted principle that meteorological advice should be given at all aerodromes by scientifically trained meteorologists and by personal intercourse between these meteorologists and pilots is a sound one and should be retained. Its application has led to the appointment of a considerable number of scientists to such posts. The rapid development of aerial transport has, however, already brought it about that practically the whole time of these assistants is taken up by the routine of safeguarding aviation. They have hardly any opportunity for scientific research, yet such research is essential if we are to have at the stations first-rate scientific personnel and if we are to make adequate use in the development of our science of the valuable observational material which aviators are collecting for us. A far-sighted policy on the part of the responsible authorities of the [German] Empire and its component states is needed if these difficulties are to be overcome.

In conclusion, I will set out the lines of development which appear

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to me to be necessary for the various types of aerological observing station :

1. *Pilot balloon stations* are already available in sufficient numbers. If found necessary, the number can be increased or the distribution altered at but little expense.

2. *Kite or kite balloon stations.*—At the present time ascents of this kind are made regularly at only three stations in Germany, Lindenberg, Rostock (Pomerania) and Lake Constance. Ascents are made in the early morning and again about mid-day. I attach much more importance to increasing the number of such stations than to increasing the number of ascents at each. We require kite stations in the east and west of the [German] Empire. The Taunus Observatory and Königsberg might do. Kite or kite balloon stations would still be essential even if the number of stations from which regular aeroplane flights are made for meteorological purposes should be largely increased. Kite balloon ascents can be carried out on many occasions when aeroplane ascents are impossible. Fog and low heavy clouds will always present serious obstacles to the aeroplane. Once suitable equipment has been provided, the cost of a kite ascent is negligible and a large and expensive personnel need not be provided. An aeroplane ascent undertaken for meteorological purposes aims at reaching a high altitude; that is not the essential aim at a kite station. The lower layers can be explored under almost any conditions either by kite or captive balloon. In thick weather wind direction at different levels can be determined during the ascent and broadcast without delay. For these and other reasons I consider that kite stations will remain essential also in the future.

3. *Meteorological Flights.*—At the present time there is only one station in Germany from which meteorological aeroplane ascents are made regularly, viz., the station at Staaken, westward of Berlin, which is associated with Lindenberg. Ascents formerly made for the *Seewarte* from the aerodrome at Fuhlsbüttel have been discontinued. Experience at Staaken has proved the great importance of such ascents. Details will be found in the last Yearbook of the Observatory. I am very gratified to learn that the Ministry of Transport proposes to establish additional meteorological flights to co-operate with our aerial ports. Such stations will not merely cater for the immediate needs of the flying service, but will be of inestimable value for scientific research. To-day the machines assigned to the Observatory are capable of reaching 7,000 m. If machines specially constructed for work at high levels were assigned, it would not be difficult, with suitable precautions, to double that height, and then our aerological dream that man can actually enter that mysterious region which has only recently come to our knowledge would become a reality.

A Remarkable Halo Complex.

The following extract from the log of H.M.A.S. "Moresby," Captain J. A. Edgell, O.B.E., R.N., is copied from the *Marine Observer*, November 1926, p. 188 :—

> "November 4th, 1925. Whilst at sea off the Keppel Is. on the east coast of Queensland, in position latitude 23° 66½′ S., longitude 150° 57′ E., at about 08.00, a portion of a halo was observed above

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the upper limb of the sun, apparently reflected on to a semi-transparent and misty cloud. Shortly afterwards the halo was observed below the lower limb, and at 08.15 a complete circle was formed. The phenomenon then extended rapidly and by 08.30 was fully developed, as indicated in Sketch 3 [Fig. 1].

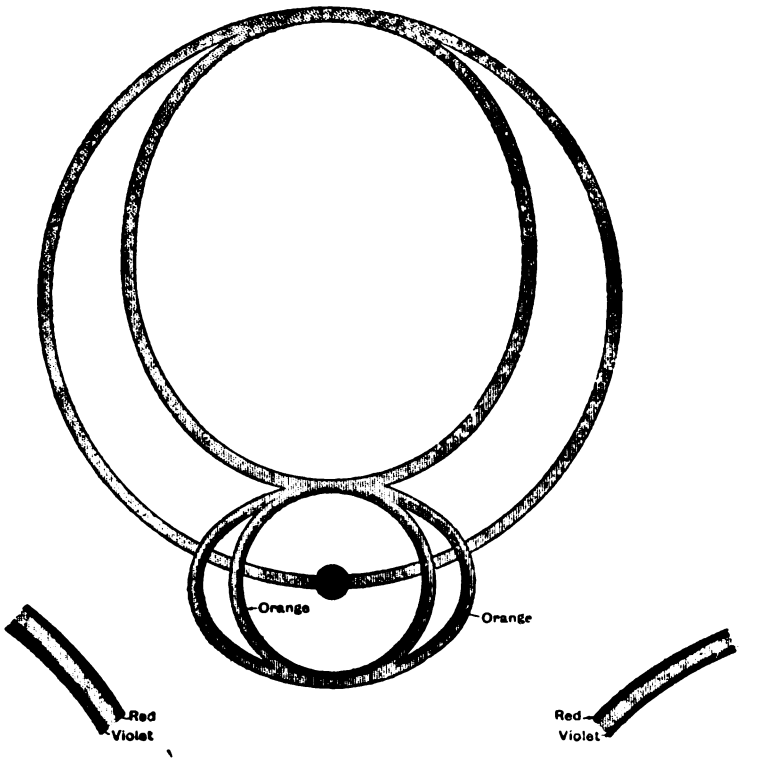

FIG. 1.

(The above illustration is reproduced from the *Marine Observer*, November 1926, by kind permission of the Controller of H.M. Stationery Office.)

"The various rings were distinctly visible from 08.30 until 08.45, when the outer ones began to fade, and at 09.30 a single halo round the sun only remained; this gradually faded, the last portion visible being that below the lower limb, which finally disappeared at 10.45. During practically the whole time that phenomenon was visible the brightest and clearest portions of the circle were the segments of the original halo immediately close and below the upper and lower limbs.

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"The colours of the spectrum were clearly seen as indicated in the sketches; the large circle with the zenith as centre and the large ellipse were of a faint white colour like white clouds.

"The altitude of the sun at 08.40 was 47° and the angular distance of the circumference of the inner halo was 22¼°. The weather was fine, a few cumulus clouds were about, and there was a light easterly breeze."

The three sketches which have not been reproduced here merely show parts of the halo of 22°; the colours indicated are orange (inside), yellow and violet. Interest centres in the fully-developed halo complex.

As to explanation, we note that the ellipse which circumscribes the halo of 22° and the brilliant infra-lateral arcs at about 46° from the sun are well known to be produced by the refraction of light through crystals in the form of hexagonal prisms floating with their axes horizontal. The circumscribing halo is due to light passing in and out of each crystal through two faces making 60° with each other. The infra-lateral arcs are due to light passing through faces at right angles to each other—one face, the base of the prism, being vertical. Whether the only condition needful is that the crystals shall have their axes horizontal is in dispute. Some investigators consider that the upper and lower faces must also be horizontal, and that the light which enters a crystal through the base (which is vertical) emerges through a face inclined at 60° to the horizon. Careful measurements of the position of infra-lateral arcs to serve as a check on theory are wanting and wanted.

The horizontal circle through the sun in our halo complex can hardly be called a parhelic circle as no parhelia (mock suns) were observed. The circle, being white, must be attributed to reflection and, being horizontal to reflection at vertical faces. The absence of parhelia tells us that there were no crystals in the form of prisms with vertical axes. The vertical faces were presumably the bases of prisms with horizontal axes, but the possibility that they were the sides of prisms with horizontal axes also deserves mention.

The "large ellipse" is the most exceptional feature of the halo complex. Oblique arcs through the anthelion are well known, though rare. In the present case the "large ellipse" is shown as touching the parhelic circle at the anthelion and the 22° halo at its highest point.

The oblique arcs have been portrayed in half a dozen cases as reaching from the anthelion to the sun, but in one classical instance, that observed by Löwitz at St. Petersburg on July 18, 1794, they terminated above the sun at the top of the 22° halo. Agreement has not been reached as to the theory of oblique arcs through the anthelion; the present instance in which the arcs were simultaneous with the infra-lateral arcs is therefore of importance.[1]

[1] Contact of the oblique arcs through the anthelion with the halo of 22° is in accordance with the theory propounded by Hastings (*Mon. Weath. Rev., Washington*, June 1920). In the complex observed at Ellendale, North Dakota, on March 8, 1920, there appeared both oblique arcs reaching from the anthelion to the sun and also a circle surrounding the zenith and touching the 22° halo (*Mon. Weath. Rev., Washington*, October 1922). A valuable discussion is to be found in a paper by L. Besson, "L'Anthélie, les paranthélies et les halos blancs," *L'Astronomie*, September 1923, pp. 271-384.

F. J. W. WHIPPLE.

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Broadcast Talks on Weather.

It is proposed to publish from time to time in the *Journal* the series of broadcast talks on weather topics which have been arranged between the Royal Meteorological Society and the British Broadcasting Company. Some of these talks have already been delivered, and the first two of the series, (1) *The Effects of Weather on Plant Life* by Ivan D. Margary and (2) *Rain* by Dr. Hugh Robert Mill, are printed in the present number. Others will follow in due course.

The Effects of Weather on Plant Life. Broadcast Talk No. 1 by Ivan D. Margary, M.A.

This talk is the first of a series arranged by the Royal Meteorological Society upon the weather as it affects our daily life. The Society was founded in 1850 for the purpose of spreading knowledge about the weather at a time when the subject was hardly recognised officially. Although entirely independent, it works in the closest harmony with the Government Meteorological Office, which during the life-time of the Society has grown to its present importance as a Department of the Air Ministry.

With H.M. the King as Patron, the Royal Meteorological Society counts among its members the leading meteorologists of the world, as well as hundreds of humble enthusiasts. Its work has been useful and valuable. It was the pioneer organisation for the collection and publication of daily weather records, a work now undertaken by Government in most countries as one of the essential public services.

The study of the weather must have begun in man's earliest stages, when he was only a hunter. When he learnt to herd flocks, still more when he began to cultivate the soil and to adventure on the sea, the need for weather wisdom met him at every turn. No wonder that the great religious festivals of pre-Christian days celebrated the chief seasonal events. There was Yule-tide, when first one could rejoice in the knowledge that the days were lengthening. Then came the feast of Spring, when leaves and flowers first appeared, to be followed by Midsummer in its glory of sunshine, and leading in due course to the feast of Harvest, when Autumn filled storehouse and barn. But only in the last two centuries, since the invention of the barometer and thermometer, has weather knowledge become exact enough to bring it into the circle of the sciences.

When we think of the weather, do we not consider it chiefly in relation to its effects on life, both animal and vegetable? If we live in the country we are constantly observing its effects. Sometimes it may be the untimely frost which nips our flowers at an unexpected moment; it may be a long drought that withers up the crops, or a sudden downpour that catches us unawares, and perhaps even hinders our progress with floods. These are extreme examples which force the influence of the weather upon the attention of anyone, but its continual daily and hourly changes are always exerting their effects on the life around us.

After a spell of raw cold in early January an hour or two of mild weather will set the thrushes singing. Most of us know the pleasure which the sight of the first upthrusting spike of snowdrop or daffodil gives, and how its date of appearance may be delayed by cold, unfavourable weather; while the first burgeoning of hedges and trees is a signal of Spring which brings joy to dwellers in town and country

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alike. Then there is Summer, marked by the familiar outburst of flower on horse-chestnut, hawthorn and dog-rose; followed all too quickly by Autumn, with its splendour of golden tints on harvest fields and trees, so soon to close the pageant of the year by dropping, as it were, a russet curtain to the ground when the first frosts come. Thus we have a continuous procession of events, many of them quite obvious and well known, which are all dependent upon the weather both as regards their date of occurrence and the actual success or abundance with which they are attended.

Observations of these things are very interesting, and records have long been kept by an enthusiast here and there. In one case recently brought to my notice a Norfolk family had kept up a continuous series of notes in the same place for 190 years, throughout five generations. But for the country as a whole, records are not of much value unless they are kept at many places on some uniform plan, and are collected and summarized by some central agency. Then indeed they give more important information than the individual observers would suspect.

The value of such combined effort is well shown in the case of rainfall. In 1860 the late Mr. G. J. Symons founded the British Rainfall Organization, a body of voluntary observers, which now receives some 5,000 records annually and is an important branch of the Meteorological Office. Much of the work of the Royal Meteorological Society is concerned with the physical study of atmospheric movements and is necessarily technical, but in 1874 it started a similar scheme for co-operation by voluntary observers in recording dates of the opening of flowers and the passage of birds. This scheme was simplified in 1890, and since then the records have been made yearly on the same plan. These observations include the dates of flowering of eighteen common and easily recognizable plants, the arrival of the well-known Spring migrants, swallow, cuckoo, nightingale and flycatcher, and the appearance of the bee, queen wasp, and three common butterflies. An additional list of Spring migrants, such as chiffchaff, house-martin, swift, etc., is also included for observation by those observers whose knowledge of birds is more advanced.

Records are now received annually from over 300 voluntary observers in all parts of the British Isles, and are collected and summarized by a Committee of the Society, the results being published in the *Quarterly Journal.*

Similar reports and notes are collected by many members of the British Empire Naturalists' Association, a Society of nature-lovers founded by Mr. E. Kay Robinson, so well known to listeners through his talks on Nature Study from the London Station. These are published in their very interesting little magazine *Country-side*, from which they are incorporated with the Society's own records.

When these plant and bird records, collected on a uniform plan all over the country, are compared, very interesting results appear. The average of thirteen of the principal plants observed shows that as a rule these come into flower nineteen days later in Northern Scotland than they do in the South of England. Taking the whole series of years since 1890, the latest year was 1891, and the earliest 1893. In 1891 the dates of the thirteen plants averaged 22 days later than in 1893, while the records of individual plants showed that many were later by more than a month in some districts.

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In districts where sufficient observers are available, it is possible to set out the results of each observing station on a map, showing areas where the plants are relatively early or late. One of the most obvious features of these maps is a strip of early dates around the Bristol Channel and often extending right up the Severn Valley well into the Midlands. This is clearly due to the warm south-westerly winds having a free passage over this area. The high ground of the Pennine Chain is naturally marked by a long strip of late dates due to the altitude and exposed situation. Another well-marked late strip runs from London north-eastwards to the East Norfolk coast. Altogether, the annual maps illustrate the march of the flowering dates and passage of the migrants from early to later areas in a very interesting way, and show many curious variations and local features. When compared with similar maps giving the distribution of mean temperature or sunshine, it is often seen that the plant variations are closely related to conditions of temperature and sunshine.

Though these results are obtained from records of quite simple plants, it should be remembered that they are only indications of general conditions affecting all vegetation. Therefore, information thus obtained is of general value, and is already proving important for agriculture. This branch of meteorology is known as "phenology," which simply means the "science of appearances."

Now to be properly representative of the country we should have observers distributed equally all over it. South of a line from Colchester to Gloucester and the Bristol Channel the distribution is satisfactory, with the one exception of Wiltshire, but elsewhere, especially in Scotland, Central Wales, Southern Ireland, and the more rural parts of England, additional observers would be doubly welcome. The observations required are so exceedingly simple that anyone who is at all interested in such things is perfectly capable of taking them. I feel sure that in districts where at present we have few observers there must be many who could observe well and would thoroughly enjoy it, if only they knew of the Society's scheme. The work soon grows most fascinating, especially to those who have learned to love the *Selborne* of Gilbert White, the pioneer of phenology. I appeal strongly to all interested listeners in these districts to send a post-card at once for an observing form. It will help us greatly to have your applications *now*, and it will give you time to see what is required and to find the best points for observation. The address is:—

The Secretary, Royal Meteorological Society,
49, Cromwell Road, London, S.W.7.

No expense is entailed beyond the halfpenny stamp required for returning the form to us at the end of the season, and as some return for their trouble a copy of the annual report is sent gratis to careful observers.

We shall be most grateful for any help in the districts named, nor would we wish to exclude any keen observer in the southern area. Full instructions are given on the observing form.

In conclusion, I would like to take this opportunity of personally thanking, on behalf of the Society, those of our present staff of observers and members of the British Empire Naturalists' Association who may be listening to this talk. We really do appreciate the interest and trouble you take in collecting the records, and giving us additional notes

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and observations. Your continued support is a great encouragement to us, and we try in return to put your records to the best possible use.

Rain. Broadcast Talk No. 2 by Dr. Hugh Robert Mill.

Shakespeare said:

> "A long time ago, the World began
> With heigh-ho! the Wind and the Rain!"

and we know that it has been raining, at intervals, ever since.

To many of us rain presents itself only as a discomfort or a misfortune, but surely this is a mean way of looking at it. A wider view recognizes rain as one of the beneficent powers of nature. It is, indeed, part of the vast circulation of water which does for our world all that the circulation of blood does for our bodies. Rain is the arterial flow pulsing from the heart of the atmosphere which carries life and power through the channels of rivers and springs over the surface and into the substance of the land. Evaporation, like the flow through the veins, brings the stream back to the heart, purified and undiminished, to begin the ceaseless round again, ministering to the welfare of plants and animals and making this country of ours a land fit for us to live in.

The Royal Meteorological Society promotes the study of climate and weather, and is a meeting-place for the official and private persons who are now investigating, and hope in time to understand, all the movements of the air and the effects which these movements produce.

The Society has asked me to speak to-night about the branch of the great tree of the knowledge of weather which is concerned with rain; but time, superior to all societies, limits me to one of the twigs of that branch, and the twig I choose deals with rainy days in the British Isles.

I wish that I had time to tell you about the life-work of George James Symons, who began sixty-six years ago to collect observations and to encourage observers of rainfall, and about the British Rainfall Organization which he established as a private enterprise and which now flourishes as an important department of the Meteorological Office of the Air Ministry of the Government. Many of you belong to it as rainfall observers and of course know all about it, but to you other listeners I may say as an item of news (the copyright in which is not reserved) that at nine o'clock (Greenwich time) this morning the rainfall, if any, was measured by some 5,000 people of every social grade scattered over every county of England, Wales, Scotland and the two Irelands, as well as in the Channel Islands and the Isle of Man. They did this yesterday, they will do it to-morrow and so on throughout the year, and "ever after," not because they are paid to do so, but out of pure goodwill. I know of no other instance of such a great and sustained voluntary service to Science, and it is on the reports of those observers that all our knowledge of British rainfall is founded.

Speaking generally, some rain falls on 150 days in the year in eastern Essex, and on an increasing number of days farther west until 240 days with rain may be expected yearly in western Ireland and the Hebrides.

The amount of water which falls as rain upon this country on an average day would cover the surface to the depth of about one-tenth of an inch. You may think this a trifling amount which soon vanishes away, but one-tenth of an inch of rain on an acre weighs ten tons.

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and so the British Islands with about 75 million acres import from overseas 750 million tons of pure distilled water in one day, or more than all the shipping that enters all our ports could carry in ten years.

The real interest of the study of daily rainfall does not arise from big figures like these, but from the diversity and uncertainty of the distribution of rain in space and time. In order to deal with all parts of the country at once, meteorology must ally herself with geography, and for the last 25 years the experts of the British Rainfall Organization have constructed an accurate and detailed map of the rainfall of every remarkably wet day. No two of these rain maps were ever quite alike; but there are three kinds of rainy days so different from each other that they may be taken as types around one or other of which all the kinds that can occur may be grouped.

The simplest type is produced by what we may call land rain because its fall is regulated by the forms of the land surface. It occurs usually in quiet weather and typically when the wind is blowing steadily from the Western Ocean. On such a day, although the air is heavily charged with moisture, no rain is falling on the Atlantic and hardly any on the low, flat islands of the Outer Hebrides or the great Central Plain of Ireland, or the Cheshire Plain; but the slopes of the hills facing the sea are rustling with rain-drops, and the steeps of the mountain groups in Ireland, the long rampart of Wales, the flanks of the Pennine Chain, the valley-cleft dome of the Lake District, the seaward front of the Galloway hills and the mighty Bens of the Western Highlands are streaming with a steady downpour. Meanwhile, over the mountain-tops thick clouds darken the sky; but beyond the eastern slopes the rain is slight and the eastern lowlands of Great Britain are dry and open to the sunshine or the stars. Land rain is usually light, but it occurs so often that the map of total rainfall for any year shows the close relation of high rainfall to high land.

The cause of land rain is that warm moisture-laden air moving in from the sea in a level drift begins to rise on meeting the first slope of the hills and rises faster and higher as it is driven against the mountains. When air rises it cools, and as it cools the water vapour condenses and comes down as rain. Thus the rain falls most heavily where the wedge-like action of the sloping land forces it to rise highest. The hills are always in the same place, so rain always falls on them in the same way when the wind blows from the same quarter.

The second type of rainy day is produced by storm rain. It comes in the storms which accompany the passage of those depressions or secondaries with which the weather forecasts are so much concerned. Storm rain shows no clear relation to the forms of the land, for as it rushes on the wings of the wind it descends in deluges equally on the high and the low, on mountain, hill and plain, and even on the level sea itself.

Storm rain is, however, clearly related to the path by which the depression causing it crosses the country. These paths may run in any direction. Very often they lead from west to east or from south-west to north-east; sometimes they go from south to north, occasionally from north to south, and very rarely from an easterly to a westerly quarter. In whatever direction the depression is moving the belt of heaviest rain which accompanies it runs parallel with the path and at some little distance to the left of it. Thus, a depression moving northward through the Irish Sea brings the heaviest rain to eastern Ireland; while one

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moving southward through the Irish Sea brings the heaviest rain to Wales and western England. Storm rain may last for 24 hours at one place, sometimes longer; but usually its duration is shorter. It may affect a very large area.

Such rain produces the most serious and widespread floods, and in the centre of the storm's force the biggest rainfalls on record have been measured. The great Norfolk rain of August 25-26, 1912, when a depression passed northward through the North Sea, yielded more than two inches of rain over 6,000 square miles and eight inches fell in 24 hours in the wettest spot. The great Somerset rain of June 28, 1917, when a depression passed eastward along the English Channel, culminated in a deluge of over nine inches in the one day at Bruton. These cases are nearly unique; but no place is safe from the risk of such a calamity, yet as a rule three inches of rain is a very heavy day's work for a British storm.

Storm rain is produced like every other kind by the rising and cooling of warm moist air, but the wedge which lifts the air in a depression or secondary is not a solid land slope but a moving mass of cold air forced by the surface wind underneath the warm moist air, which it hoists up bodily on its back into the cold, upper region, whence the rain descends.

The third kind of rainy day is produced by the thunder rain of summer, which has its own wild way, paying heed neither to the paths of depressions nor to the forms of the land as it crashes down on some unhappy spot with a sound that almost quenches the thunder. The distribution of this type of rain can only be studied effectively in those parts of the country where rainfall observers cluster most closely, for in thunder rain a few hundred yards may separate a place with no rain from one where an inch or more falls.

On a hot summer afternoon when a typical thunderstorm is in action, heavy rain falls not continuously but patchily on a series of small irregular areas seldom more than a few miles across, separated from one another by intervals where the rain is light, and strung out in straight parallel bands across a great expanse of country. The parallel bands of alternately wet and dry patches are separated from each other by considerable breadths where little or no rain is falling. Most people will tell you that compared with their neighbours, their homes are free from severe thunderstorms because they see many such storms which approach but then diverge to right or left before they burst. This observation is explained by the fact that when a house happens to lie in one of the dry strips or in one of the comparatively dry spaces, terrific downpours are usually to be seen from it in the wet patches not far away.

When the exceptional case occurs of a thunderstorm straight overhead, the result can be disastrous. At the centre of intensity the fall of rain has been compared to a deluge of end-on stair rods, and this is often mixed with hail which may be as large as golf balls. Great damage is done every year by such thunderstorms to greenhouses, windows and gardens. Every leaf may be beaten from trees and herbs and a whole garden ploughed and pitted as if by an intense machine-gun fire, and all this is the work of rain or hail, not of lightning.

Thunder rain, like every other kind, is formed by the uprising of warm moist air. Its peculiar ferocity comes from the exceptional force

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of the uplift, caused probably by local heating, and a measure of the height to which the air is hurled up the chimneys of a thunderstorm is given by the large hailstones which can only be formed in the extreme cold of the higher regions of the atmosphere. As much as 3½ inches of rain or melted hail has been known to fall at a spot in the Thames valley in a single hour during a great thunderstorm, but fortunately such severe storms are very rare.

In describing the three types of rainy days due to land rain, storm rain and thunder rain, I have touched only the fringe of the magic carpet of rainfall woven from the few daily minutes devoted by the thousands of British rainfall observers. A fuller discussion of the results has filled a volume every year without a break since 1861, and the work goes on. The rainfall of the various months and the rainfall of successive years show variations as striking and relationships as intimate as those we recognize in rainy days, but they belong to other twigs of this branch of knowledge.

The collection and discussion of great masses of figures involves much monotonous work; but the labour is sometimes lightened by gleams of watery humour. I bid you farewell with one of these, arising from the report by a clergyman of the measurement of 6.11 inches of rain one Sunday morning and his subsequent explanation that the enormous figure was due to having copied in place of the rainfall (which was *nil*) the amount of the morning offertory, which was 6s. 11d.

REVIEWS.

Scott's Polar Journey and the Weather; being the Halley Lecture delivered on May 17, 1923. By G. C. SIMPSON. Oxford (Clarendon Press), 1926. 8°. Pp. 31. 2s. 6d. net.

This lecture, which was delivered three years ago, is a detailed study of that remarkable episode in Antarctic weather, the tragic consequences of which stirred the sympathy of the world more deeply than any polar catastrophe since the loss of Sir John Franklin. Every Antarctic land traveller has run the risk of such a series of disasters as that which caused the death of Scott, Wilson, Oates and Bowers in 1912. Had one of the storms which so often imprisoned Shackleton, Mawson and the others in their tents lasted but a little longer, they would inevitably have perished like Scott. While if the storm which was fatal to him had lasted not quite so long, he might be with us now.

Dr. Simpson gives a lucid and masterly discussion of the origin and sequence of weather changes during the fatal Antarctic journey with personal touches of loyalty to his old leader and a generous understanding of the difficulties under which he succumbed.

Dr. Simpson is careful to show that the physical geography of the region is the key to its meteorology. He makes real to the reader how the various features of the land stand in the boldest contrast, the Plateau to the west averaging some 8,000 feet in height separated by an abrupt mountain wall from the level ice-laden sea in the northern half and from the equally level Ross Barrier at a height of 170 feet in the southern half. The route to the Pole from winter quarters lay for 422 miles on the Barrier, for 129 miles on the steep slope of the Beardmore Glacier, and for 350 miles on the Plateau. Normally the air temperature on the low Barrier should be at least 27 degrees higher than on the high Plateau at the same time. Another contrast is the difference between the large daily range of temperature on the Barrier, which in summer

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amounts to over 20°F., and the small diurnal variation at sea level during the same period.

These climatic conditions are disturbed by the characteristic Antarctic weather changes produced by blizzards, and perhaps the most important feature of the lecture is the discussion of this phenomenon. Dr. Simpson points out that the blizzard occurs only on the west side of the Barrier near the Plateau wall. Amundsen encountered none in the eastern part of the Barrier. He shows that in calm weather the temperature on the Barrier is enormously reduced by radiation, the cold layer sometimes extending to a height of 4,000 feet, and whenever a wind springs up this air is dispersed and normal air temperatures are restored, only to be reduced by radiation during the next calm. Thus the rise of temperature in a blizzard is merely the temporary restoration of the normal between two spells of abnormal cold. It was the lack of a blizzard which made Scott's return journey on the Barrier as cold as if he were still on the Plateau, and made the snow as hard as sand so that the sledges dragged heavily and the march was slow. When vitality was reduced to its lowest level the blizzard came, but came too late and lasted too long to save the party.

Dr. Simpson does not deal specifically with the origin of blizzards, but refers to the concentration of cold stagnant air on the Barrier by local cooling as the origin of the particular blizzard which was fatal to Scott. We should like to have from him a more detailed statement on this subject, taking into account the effect of cold air flowing down from the Plateau, the occurrence of which seems the most natural explanation of the absence of blizzards in the east, and of the great thickness of the stratum of cold air in the west of the Barrier. We recognize that this would be outside the scope of the lecture, but the lecture is so good that one cannot suppress the natural instinct of wishing for more.

H. R. M.

Tropical Cyclones of the Pacific. By STEPHEN SARGENT VISHER. Bernice P. Bishop Museum, *Bulletin* 20, Honolulu, Hawaii, 1925. 8°. Pp. 4 + 163.

In obtaining the information upon which this work is based the author visited Hawaii, Fiji, Australia and the Far East, and discussed his subject with men who have spent a large part of their lives in studying tropical cyclones at close quarters. In addition, he has been able to devote a year entirely to this one piece of work. A year may not seem a very long time in which to study the storms of such a vast area as the intertropical portions of the Pacific, which extend from east to west across fully twelve thousand miles of ocean, but it has proved long enough to enable him to collect a great quantity of useful information, and his experience and skill in handling meteorological data has enabled him to record this information in an attractive way in a book which runs to less than two hundred pages. This achievement is the more remarkable in that he has dealt at some length with the biological importance of tropical cyclones, in particular as regards the distribution of life among the islands of the Pacific, as well as with the ordinary problems to which the study of these storms leads. The bibliography contains as many as 209 references, and of these a large number are references to works of importance, involving much research.

For the benefit of those who are unable to spare the time necessary for reading the book with the thoroughness which it deserves, a few of the items which tend to modify existing views about tropical cyclones may be mentioned. It appears that no portion of the intertropical Pacific is free from cyclonic storms, and time may show that the frequency of their occurrence over the different portions of this area is not so varied as might be supposed; at present there is an apparent correlation between

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the frequency of cyclone formation and the average number of educated white men in the region under consideration, which shows how many storms are never recorded. Many storms originate within 8° of the equator, and not a few have been observed within 4°. The tendency to regard the cyclones of one part of Oceania as distinct from those of another part seems to have drawbacks, and the fact that Australian storms can be traced sometimes for 9,000 miles, without any decrease of intensity being observable, suggests that Kimball's idea, that some of the storms that develop off the west coasts of Central America and Mexico may pass across the Pacific and appear as typhoons in the China Seas, may be correct. Information about the number of cyclones that occur in the Pacific is still very incomplete, but it is almost certain that the average number in a year exceeds fifty. The number that pass out of the tropics and affect markedly the weather in temperate latitudes is much larger than is generally recognized. Both Froc and Okada have traced typhoons far into Asia, and have noted a great increase in their intensity when they have at last reached the ocean again; they believe that most typhoons will eventually be found to give rise to extra-tropical cyclones.

Departures from the ideal cyclone of meteorological text-books are numerous, but it is perhaps not generally known that one or more secondary centres, apparently analogous to the secondary depressions associated with temperate "depressions," are by no means uncommon, and have been noted repeatedly in the Far East. The question of a connection between the number of sunspots and the frequency of Pacific cyclones has been dealt with rather thoroughly, and the statistics contain no suggestion of any such connection.

Mr. Visher may be heartily congratulated on the production of a valuable and much-needed contribution to meteorological literature. One criticism may be ventured upon, and that is the absence of an index; an index seems particularly desirable in a work dealing with a subject which is so hard to condense into a readable form, and the detailed table of contents does not quite take its place. Printer's errors and small slips are rather numerous, and there are several erroneous references; these should be attended to if a new edition is brought out.

E. V. NEWNHAM.

Australasian Antarctic Expedition, 1911-14, under the leadership of Sir DOUGLAS MAWSON, O.B.E., F.R.S. *Scientific Reports*, Series B.

Vol. I., Terrestrial Magnetism. Pp. 285, plates 18. Part I., Field Survey and Reduction of Magnetograph Curves by ERIC NORMAN WEBB, D.S.O., M.C., Chief Magnetician to the Expedition; Part II., Analysis and Discussion of Magnetograph Curves by CHARLES CHREE, F.R.S.

Vol. II., Part I., Records of the Aurora Polaris by DOUGLAS MAWSON, Kt., F.R.S. Pp. 191, plates 6.

As explained in the Preface to Vol. I., publication was seriously hampered by the world war. Mr. Webb acknowledges the valuable support given in the loan of instruments and the training of observers by the Carnegie Institution of Washington; also the valuable assistance given by Prof. Coleridge Farr and Mr. H. F. Skey, of Christchurch, New Zealand, in supervising the work that went on whilst he himself was serving in the Australian Forces. The principal part of Mr. Webb's work relates to the main base station at Cape Denison, Adelie Land (67° 0′ S, 142° 40′ E); but we have in addition magnetic results from Macquarie Island (54½° S, 159° E), from a western base station "The Grottoes" in Queen Mary Land (66° 20′ S, 95° 2′ E), and from a variety of sledge journeys. Two of these journeys, one in Queen Mary Land and the other in the adjacent Kaiser Wilhelm Land, were made by the

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staff attached to the western base station, the others by the staff attached to Cape Denison. The most ambitious and interesting was directed southwards towards the magnetic pole. It covered about 300 miles, rising to nearly 6,000 feet above sea level, and attaining a dip within 0°.3 of the vertical. The results of this and of earlier expeditions are utilised by Mr. Webb in a discussion of the position of the south magnetic pole, summarized in a chart on p. 55. Owing to the large diurnal changes the magnetic pole must be regarded as an area, not a point. Mr. Webb concludes that in 1912 the centre of this area lay about 71° 10′ S, 150° 45′ E, and that secular change is carrying it in a N.W. direction away from the geographical pole.

Tables are given on pp. 100 to 197 of hourly values of *D*, *H* and *V* (declination, horizontal force and vertical force) from April 1, 1912 to August 7, 1913. Various interesting aspects of the field work and the observers are illustrated in the first eleven plates at the end of the volume. The remaining plates show diagrammatically the regular diurnal variations derived from the curve measurements. The discussion on pp. 199 to 285 by the present writer refers mainly to the diurnal inequalities and to the absolute daily ranges. The two most outstanding results are the large amplitudes of the daily ranges, and the great effect of disturbance on the regular diurnal variation. Out of 469 (Greenwich) days there were only two in which the daily range of declination did not exceed 30′, while there were 45 in which it exceeded 5°. In the winter of 1913 the amplitude of the diurnal inequality of *H* derived from about five disturbed days a month was six times the corresponding amplitude derived from the selected quiet days. The discussion of magnetic storms and their relation to aurora is reserved for a future volume.

The auroral observations discussed by Sir Douglas Mawson refer to three places, viz., Cape Denison (1912-13), "The Grottoes," Queen Mary Land (1912), and Macquarie Island (1912-15). The observations at Cape Denison are much the most complete, filling 116 of the 131 pages devoted to auroral observations. Sometimes the sky was obscured by clouds or drifting snow for several successive days, but in general, except on these occasions, when aurora was not seen the fact is explicitly stated, and sometimes with an additional reference to cloud, snow-drift or moonlight. When aurora was seen, its type (arch, band, curtain, glow, patch, etc.), its greatest altitude, and the direction in which it appeared, are usually given. The results are discussed on pp. 143-188, and on pp. 189-191 there is a description of six plates at the end of the volume —one of them coloured—which show various auroral types. At Cape Denison and "The Grottoes," aurora occurred most frequently in the north, *i.e.*, the direction opposite to the magnetic pole, and at Cape Denison N.N.E. was the most common direction. At Macquarie Island, about 800 miles further from the magnetic pole, aurora was generally well down in the southern sky, but colour other than the normal greenish-yellow was more in evidence there than in the Antarctic. At Cape Denison, "on 52 per cent. of all hours of moderate twilight and darkness, and including all moonlight hours, when the sky was clear for observation, auroral lights would be seen at least some time within the hour." And it should be remembered that faint aurora cannot be seen in twilight or anywhere near a bright moon. Sometimes the nature of a faint nebulous haze, especially during hours of faint twilight, remained uncertain. Sometimes in such cases a temporary brightening confirmed its auroral origin. There were, on the other hand, some brilliant manifestations, especially in June and July, 1912, *i.e.*, near midwinter. Speaking of one of these, Sir Douglas writes: "The seething nebulous luminescence presented the appearance of a sea of breaking waves. . . . The waves and particularly their crests were of a rose pink to red colour, whilst in the intervening areas flashes of brilliant green appeared." Sir

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Douglas discusses a number of interesting questions, including the diurnal variation of aurora. This is complicated by questions of cloud, twilight, etc. At Cape Denison the greatest frequency of intense aurora occurred an hour or two before midnight, but at least near midwinter aurora was less common then than between 5 and 7 a.m. (local time). The morning was also the time when aurora was most often seen in the zenith.

C. CHREE.

Der Massenaustausch in freier Luft und verwandte Erscheinungen. Probleme der Kosmischen Physik, Bd. VII. By WILHELM SCHMIDT. Hamburg (Henri Grand), 1925. 8vo. Pp. viii + 118. Rm. 7.

It has become evident in recent years that scientific progress in many directions is dependent on a full knowledge of the conditions and consequences of irregular turbulent flow in gases and liquids. This book is intended to be a summary of new knowledge in these directions, and, as the author points out, it should be of interest to all concerned with meteorology, oceanography, climatology, atmospheric electricity, and even botany.

The book is primarily concerned with mass-exchange in the free air. Two neighbouring masses of air can exchange mass (and therefore heat, water vapour, suspended impurities, and so on) not merely by molecular drift of particles from one mass into the other, but in general much more rapidly by vortices or eddies of various dimensions. If, for instance, the heat content of one mass be denoted by S, and of the other by S_n and the gradient between the two by S', then the resultant flux of heat is given by AS' where A is Schmidt's *Austausch* coefficient. Schmidt is careful to avoid using the term in such a way as to give rise to misconception. He makes it clear that A is a fiction, an an "apparent conductivity" or an "apparent diffusion," the summarised or mean result of a number of processes which he does not analyse in much detail and which may or may not be continuously in operation. Even in the same medium A varies with space and time. The book is full of practical examples derived from mean values of various sorts, for example, the working of convection in the atmosphere, the distribution of the salt-content in sea-water, the distribution of seeds, pollen, etc., in the atmosphere and of plankton in the sea, the variation of wind with height near ground level, the emanation-content of the air and the variation of atmospheric electric potential gradient with height.

Schmidt begins with the demonstration by Osborne Reynolds of the difference between "laminar" and "turbulent" flow of liquids. Reynolds showed, in connection with the flow of liquids through tubes, that there was for a liquid of given density and viscosity in a tube of a given diameter, a certain "critical velocity" beyond which the regular laminar flow broke up and became turbulent flow. This experiment provides an example of *Austausch* of dynamical origin. Processes originating in statical conditions, such as convection under the influence of gravity, also contribute to the *Austausch*, which in fact is the integration of all the mixing, diffusing or conducting processes at work.

A section of some interest is that on the interaction of the atmosphere and the earth's surface. The difference between solid ground or water at rest on the one hand and deep open ocean on the other hand in their capacity for disposing of heat received at their surfaces is dependent mainly on the high *Austausch* which becomes possible from the mobility of the medium in the latter case. Thus, over a sand surface rather less than four-tenths of the total energy arriving goes to the atmosphere, whilst over the open ocean rather less than four thousandths is left to go to the atmosphere. If, however, the sea surface freezes, climatic relations alter completely. Green Harbour, Spitzbergen, for example, has a "maritime" climate in summer and a "continental" climate

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in winter. In the same section the difference in the diurnal variation of temperature at various heights over land and sea surfaces is also discussed.

There is a chapter on *Austausch* and friction, including the interaction between atmosphere and sea. A short section is devoted to the part played by wind and stratification in determining the *Austausch*. The irregular flow at surfaces of separation, in particular at that between the air and the earth's surface, is the chief locus of the formation of eddies and *Austausch* streams. The general increase in *A* with height is not opposed to this idea; it arises because proximity to the bounding surface at first keeps down the vertical components of velocity in the eddies.

The last chapter is devoted to *Austausch* on the large scale, namely, between different latitudes.

The writer has a good descriptive style and develops his subject in a concise and logical manner. Every chapter is full of information, and at the end there are three pages of references which must include pretty nearly every important paper on the subject.

A. H. R. G.

The Glacial Anticyclones, the Poles of the Atmospheric Circulation. By WILLIAM HERBERT HOBBS, University of Michigan, with an introduction by HUGH ROBERT MILL, lately President of the Royal Meteorological Society. New York and London (The Macmillan Company), 1926. 8vo. Pp. xxiv + 198, pls. 3 and figures in text. $2.75.

This book, which sets out in collected form the views of its author upon the subject of the anticyclonic supplies of air in polar regions, north and south, is full of useful facts and figures, fortified by extracts from many authors, about the air-circulation over Greenland, the north polar region and the Antarctic continent.

But it is a difficult book to read and still more difficult to review. In passing, we note on p. 72 a bracket equivalent of 77°F. for a *range* of temperature of 25°C., and we wonder pathetically how long it will be before science deals with temperature in the light of the twentieth century instead of the darkness of the eighteenth. And further, a frontispiece map exhibiting a scheme of atmospheric circulation seems hardly to be related at all to the features of the pressure maps of the globe, and puts the reader into the limbo of hypothetical circulations of half a century ago.

The first requisite for a review is that the author and reviewer should attach the same meaning to the technical terms which they use; therein lies a good deal of the difficulty. The reviewer's reading of the book has failed to elicit the meaning which the author would like him to attach to the word anticyclone. Strictly speaking, the word simply means a region of high pressure on a sea-level map, and carried with it from the first the idea of surface air moving clockwise with an outward flow on all sides. Galton's original definition certainly refers to something more than the surface; it includes cold air plunging down from above, but the coldness and the plunging are matters of fantastic inference rather than of observation, and in modern practice an anticyclone is a circumscribed region of high pressure on a sea-level map, and nothing more. Any physical or dynamical properties that characterize it must be sought for by observation.

On p. 51 Professor Hobbs gives a sketch of an anticyclone covering a continental glacier, which the reader may think of as Greenland or the Antarctic continent. The slopes are marked as the "region of down slope storm-winds." Above the crown of the glacier is the "eye of the anticyclone," through which air pours downward from a level between

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five and six kilometres, while the intervening layer, three kilometres in thickness, looks on complacently, taking no part in the game. How the intermediate air is prevented from doing what the air miles above is allowed to do, no reviewer could understand without an explanation which he is himself unable to supply. On the following page (52) the author writes: "The tendency of outward moving currents (over the surface of the glacier) to produce a void over the boss of the ice-dome develops a down draught of air of anticyclonic nature above the central area." The reviewer finds it impossible to contemplate a "void" in the middle of an anticyclone. His definition of that meteor forbids such a conception. Any tendency thereto must have been suppressed at its birth, otherwise there would have been no anticyclone.

The fact that an anticyclone in meteorological practice is a sea-level phenomenon makes it almost impossible to carry on a discussion about an anticyclone over an area of the earth's sea-level surface which is already covered by a vast pile of rock, ice and snow, some two kilometres thick and hundreds of thousands of square kilometres in area.

The idea of an anticyclone can of course be extended to any level above the sea and can be carried up to the higher levels of Greenland or the Antarctic continent until a level is reached where there is no longer rock, or ice, or snow, but only air. Still, whatever may be the level, anticyclone means a distribution of pressure in a level surface, and measurement of pressure in the air over Greenland or the Antarctic continent at levels of two, three or four kilometres, are so hard to come by that a real map is unattainable. Except for a few balloon and kite ascents all that can be observed are clouds and occasionally winds. The rest is inference from very inadequate premises. Until we have a clear picture of the kinematics of clouds and winds, a discussion of the height of the Greenland or the Antarctic anticyclone is of the scholastic order. It cuts no ice.

Or take the word fœhn: the author seems to regard a fœhn as the same thing as what is often called a valley wind, what the reviewer calls a katabatic wind—that is to say, wind that flows down a valley in consequence of the cooling of the air by the ridges and sides of the valley, after they have been cooled by radiation. On p. 73 the author begins a section headed, "Fœhn effect of down-slope winds at glacier margin." To the reviewer fœhn effect and down-slope winds are incompatible terms. He keeps always in his mind an idea of fœhn wind quite distinct from that of valley-wind. Valley-wind is composed of air that goes down the valley like a river *because it is cold, being chilled by the land-surface with which it is in contact.* Fœhn wind, on the other hand, is composed of potentially very warm air that is *driven over a ridge by the general distribution of pressure,* and is carried down to the valleys on the other side, not because it is cold, but by the mechanics of eddy-motion, in consequence of which the air when it gets to the valley-bottom is not merely potentially warm but actually warm, and very dry because it has realized its potential warmth and not lost it as a valley-wind does. A valley-wind flowing down because it is cold is more likely than not to end in a fog. A fœhn wind is, so far as we know, characteristically dry.

The reviewer has not in mind all the details of fœhn in the Alps but rather the wider phenomena of the "chinook" of the western prairies, a warm dry wind coming over the divide of the Rocky Mountains, melting snow, or evaporating it, something quite different from the blizzard-winds that are valley-winds which come down cold slopes in consequence of their own gravity.

This confusion of fœhn and valley-wind finds further expression when the subject is fœhn clouds, or lenticular clouds as we prefer to call them. To the reviewer these clouds indicate certain regions of

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elevation in the eddy formed in a general current of air which passes over a mountain-ridge: to the author they seem to be part of the gravitational flow of cold air downhill. The two ideas are not reconcilable in any space allowed to a reviewer.

The real fact is that the author has got himself into very rough country by hitching his waggon to the word "anticyclone," and the reviewer would like to suggest to him the possibility and the advantages of hitching it to the term katabatic wind instead. A katabatic wind is plainly a wind that goes downhill, and the expression may be used for any current of air descending by its own gravitation. Katabatic winds are everywhere where there is a relatively cold surface and therefore are very characteristic of all glaciers and snow-surfaces, and especially the three thousand miles of the three-kilometre high slopes of Greenland and the still more extensive slopes of the Antarctic continent which are the subject of Professor Hobbs's book.

Here is a picture of the situation. Imagine a 50-foot iron mast erected on level ground, and a calm, clear night. Is there any meteorologist who would fail to forecast a coating of dew or hoar-frost on the mast, and a descending stream of cold air? In calm weather, left to itself, the descending stream is the result of an inexorable process. The mast would bring down air just as certainly as a lightning-conductor would bring down electricity. The flow might be prevented by wrapping the mast with wire and making good by electric energy the loss of heat by radiation; in fact, very interesting experiments could be made in that way. But there are no coils of wire for the purpose on glaciated mountains; they have to take the natural consequences of loss of heat, and those consequences are considerable—nothing less, in the writer's opinion as in the author's, than the general circulation of the atmosphere.

Instead of a single mast fifty feet high, imagine ten thousand masts a thousand feet high, arranged in rows five feet apart, making a little forest of masts a hundred and fifty yards square, with channels suitably arranged. The owner of such a forest could contract to supply to anybody who wanted it a fair stream of cold air on a calm night; but a breeze that might arise at any time from the general distribution of pressure would spoil his trade altogether; he might get more hoar-frost but his cold air would be mixed up with the general wind and carried away. He would be unable to deliver it.

Instead of ten thousand masts, imagine two inclined walls fifteen hundred miles long, ten thousand feet high, arranged to enclose a triangle 2,142,000 square kilometres in area, and you have Greenland; and put seven Greenlands together round the south pole and you have the Antarctic continent.

You can make similar experiments with Mt. St. Elias and Mt. Logan, with the Rocky Mountains and the Andes, with the Himalayas and the Alps. It does not even require snow or ice; but glaciation makes experimenting easier.

The katabatic winds of all such land-masses, with the superjacent winds of the general circulation, are really worthy of the consideration which Professor Hobbs gives to them under the fettering title of the polar anticyclones. One longs to see his facts released from the bondage which his title imposes upon him, and that not merely for the local interest of the subject, but because everywhere, all over the world, we have two meteorological principles relating to wind always interacting; first, the principle of the relation of wind to pressure, which is obviously dominant in what we call the free air, and secondly, the principle of downward convection along cold slopes, which produces the katabatic winds that acknowledge no laws of pressure, but those of gravity alone. There is, of course, another side to convection, the anabatic wind, but that is a different story, mainly concerned with water vapour.

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The katabatic wind is the more interesting of the convectional winds, because it is the more easily studied; it is on the surface and must stay there so long as it preserves its relative coldness, even if it has to travel all the way to the equator to get properly warm.

The fœhn wind and fœhn clouds belong to the general circulation, and therefore to the distribution of pressure; the katabatic winds belong to no circulation at all—they lose their identity when they come under the influence of the general circulation. Any student of weather-maps must agree that the general circulation, to the force of which Professor Hobbs does less than justice, always reserves the right to blow away the glacial anticyclone, or anything else that gets in its road.

Nevertheless, the katabatic wind is an element of more than local interest; it helps at least to supply the stream of cold aid that forms what is called the polar front, but might with greater propriety be called the glacial front. Quoting from a recent lecture: "The katabatic wind is in itself a fascinating study in all latitudes and it deserves enthusiastic consideration. It is the bitterest enemy of mankind. It causes discontinuity, it maintains the polar (or glacial) front, it supplies the energy that causes the convection, that produces the rain, that accounts for the wind in the cyclonic house of the Northern hemisphere, that Dove began and Bjerknes has built."

NAPIER SHAW.

Résultats des mesures photogrammétriques des aurores boréales observées dans la Norvège méridionale de 1911 *à* 1922. By C. STØRMER. *Oslo, Geofysiske Publikasjoner,* Vol. 4, No. 7, 1926. Pp. 108, pls. 48. Pris 12 kroner.

Professor Størmer is already well known for pioneer work on aurora, both on account of his theoretical investigations and for the Bossekop expeditions in 1910 and 1913. The present contribution details the height and situation of auroræ above Norway during the period 1911-1922, as deduced from auroral photographs. For computation of the height of aurora simultaneous photographs of well-defined characteristic features, together with at least two known stars, are required from two or more stations. Such photography is difficult owing to general lack of illumination and the short exposure which can be given, but very satisfactory results have been obtained by using a kinematograph lens, 50 mm. focal length and 25 mm. diaphragm, and very fast, violet sensitive plates. Cameras with similar objectives were in use at a network of stations interconnected by telephone; the main station, situated at Bygdø or Oslo, was operated by the author. The distance apart of the stations ranges from 25 to 260 km.

Measurement of the photographs and the ensuing calculations are based upon procedure adopted for reduction of the 1913 data obtained at Bossekop (*Geof. Publ., Vol.* 1, No. 5). The results show that the altitude of the lower edge of homogeneous arcs usually lies between 110 and 130 km., and that such arcs approximately follow circles of magnetic latitude. The long auroral rays follow lines of magnetic force, and during auroræ associated with violent magnetic storms and sunspots they are frequently of enormous length and situated in the region around 400 to 800 km. The radiating point of auroral coronas, as determined from 61 photographs, is found to be generally within about 1° of normal magnetic zenith.

A comparison between results obtained around Oslo and those for Bossekop and the Haldde shows that auroræ in lower latitudes penetrate nearer to the earth's surface.

Detailed descriptions are given of the displays photographed, and the tabulated matter includes heights of various forms, radiating point of coronas, and frequency of altitudes of lower limits of different types;

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there are 96 excellent auroral photographs, over 500 sketches showing the situation of characteristics used for computation, and 22 maps depicting location of the auroræ. The displays are described lucidly, but it must be remembered that in certain details the classification of types of aurora differs from that used by other investigators.

Among more unusual phenomena recorded we may mention :—

1. 8th March, 1918.—Rays were observed to undergo successive changes of colour without any change in their form or apparent position. Similar changes have been noted on previous occasions both by the author and by Vegard and Krogness.
2. 17th October, 1919.—At about 20.00 hours, an arc, probably at an altitude around 200 km., was observed south of zenith, and a photograph, which was taken shortly after midnight when only a diffuse glow was visible, shows distinct rays. These apparently occur in the ultra-violet and encourage speculation about the possibility of such rays occurring without any activity in the visible spectrum.
3. 19th December, 1919.—Weak aurora was observed to south-west at a time when no activity could be seen in the more usual directions.
4. 22nd-23rd March, 1920.—A magnificent display lasting from twilight till dawn and which yielded 620 photographs. Outstanding features were coloured coronas and long rays situated at very great heights.

The paper records many hours of work under arduous conditions, and its object, as described by the title, is accomplished in a thorough and graphical manner. Auroral theory is reserved for discussion in a later contribution. A. W. L.

Back Numbers of the Quarterly Journal.

The following numbers of the *Quarterly Journal* are out of print, *viz.*, No. **121**, January, 1902; **142**, April, 1907; **162**, April, 1912 and **181**, January, 1917. Should any Fellow having these numbers no longer desire to retain them the Council would be glad if he would kindly return them to the Society.

The following early numbers of the *Quarterly Journal* are also required : Nos. 1, 3 and 4, 1872; Nos. 4, 5 and 6, 1873; and No. 12, 1874.

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THE ATLANTIC OCEAN.

[An address delivered before the Royal Meteorological Society, January 19, 1927.]

By Sir GILBERT WALKER, C.S.I., F.R.S., President.

It has for some years surprised me that although the motions of the oceans of air and of water have much in common and depend on the same principles, students of meteorology do not as a matter of course acquaint themselves with the fundamental facts of oceanography. It is on this account that I have taken the Atlantic as my subject and I shall treat it as that ocean about which most is known, rather than as the unwitting source of much of our bad weather.

I must at the outset acknowledge my great indebtedness to Prof. Schott, of the Deutsche Seewarte, at Hamburg. It was he who drew my attention to the importance of the discoveries that have quite recently been made, largely during German scientific voyages; and the outline that I shall give you, together with the maps and diagrams, are largely derived from an admirable geography of the Atlantic that he published in 1926.

We shall begin with the surface currents and then in turn look at the temperature, saltness and density. Finally we shall consider the light thus thrown on the circulation in the ocean and some of the meteorological conclusions to which the data point.

SURFACE CURRENTS.

Our first chart of the surface currents in the northern winter reminds us strongly of the corresponding winds, but shows the equatorial stream as enormously the stronger. This stream is forced by the American continent to bend northwards and north-eastwards to become the Gulf Stream which, rapidly weakening, becomes the Atlantic Stream, thanks to which the Norwegian coast is 25°C. or 45°F. warmer in winter than the coast of Labrador in the same latitude. It may be noticed at once that the surface currents feeding into the strong equatorial stream are feeble, and that therefore there must be ascending currents from below to supplement them, while the weakening of the Gulf Stream to the north of the Sargasso Sea means that the water there is descending. It will be seen, too, that one branch of the Atlantic Stream descends out of sight after reaching the Greenland Sea while a second flows across the Barents Sea before becoming seriously weakened. Further, an arctic current flows round Greenland from east to west into Baffin's Bay and the cold Labrador current carries with it icebergs and floe ice southwards

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round Newfoundland to menace ocean shipping. In the south the Brazil Stream feebly recalls the Gulf Stream with descending currents extending eastwards from Martin Vaz, while the cold Falkland Stream reminds us of the Labrador current. The strong westerly currents between 40° S. and 50° S. resemble, too, the winds of the "roaring forties," while westward currents springing into being off the African coast at 20° N. and 20° S., involve the

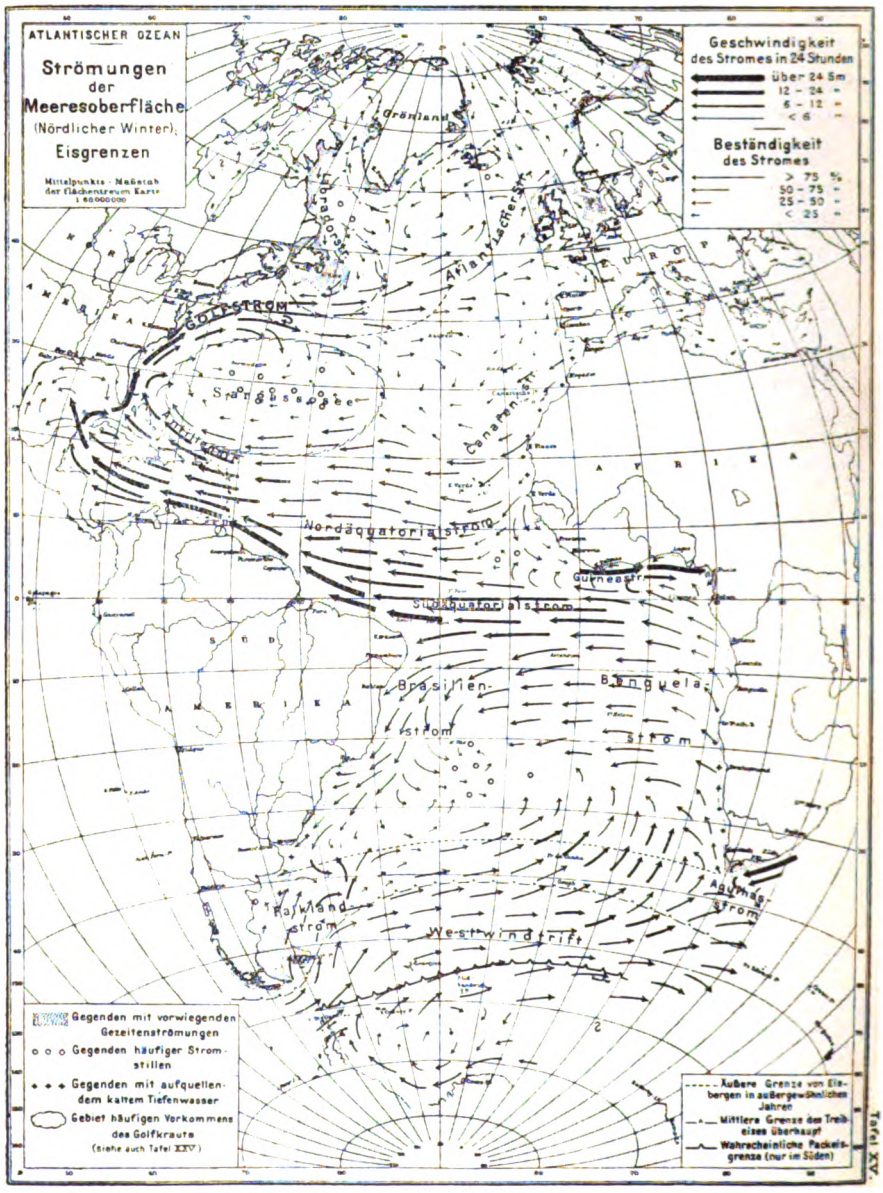

FIG. 1.—Surface currents in the northern winter.

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existence of colder currents of sea water rising from the depths below.

Temperature.

Chart II. shows the mean Centigrade temperature of the year of the surface water. This is at its maximum in the equatorial current and the contrast at 55° N. between the Atlantic Stream and the Labrador current is conspicuous. At 55° S., however, Bouvet I.

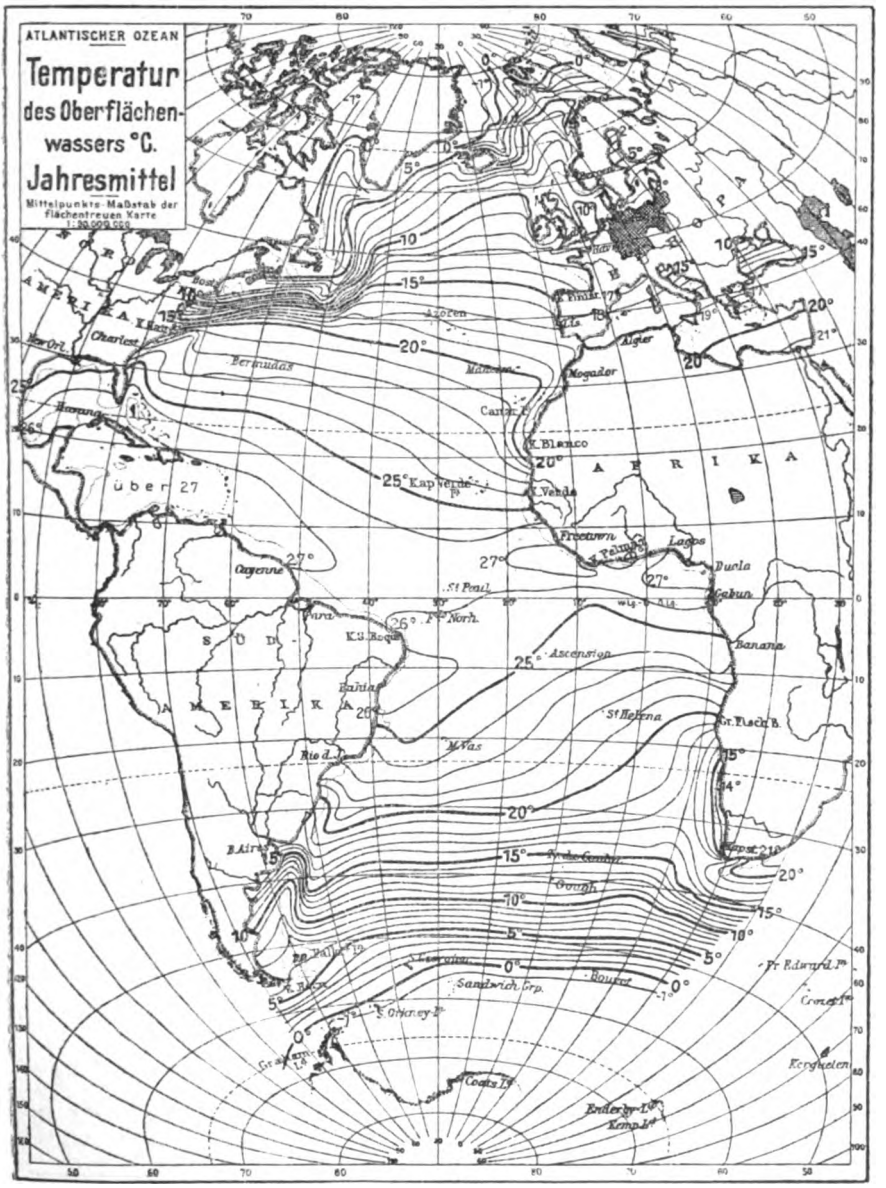

Fig. 2.—Yearly mean temperature (centigrade) of the surface water.

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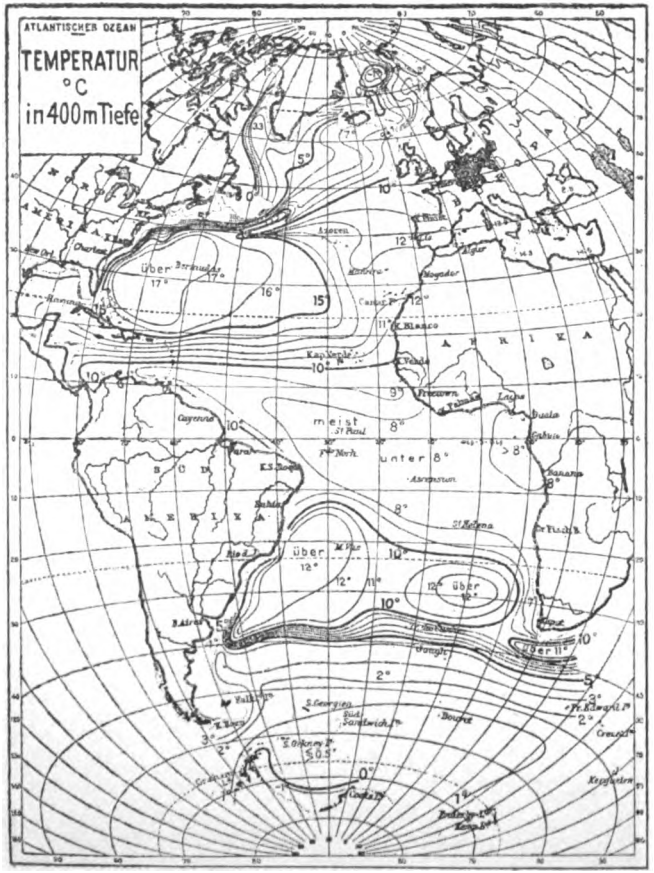
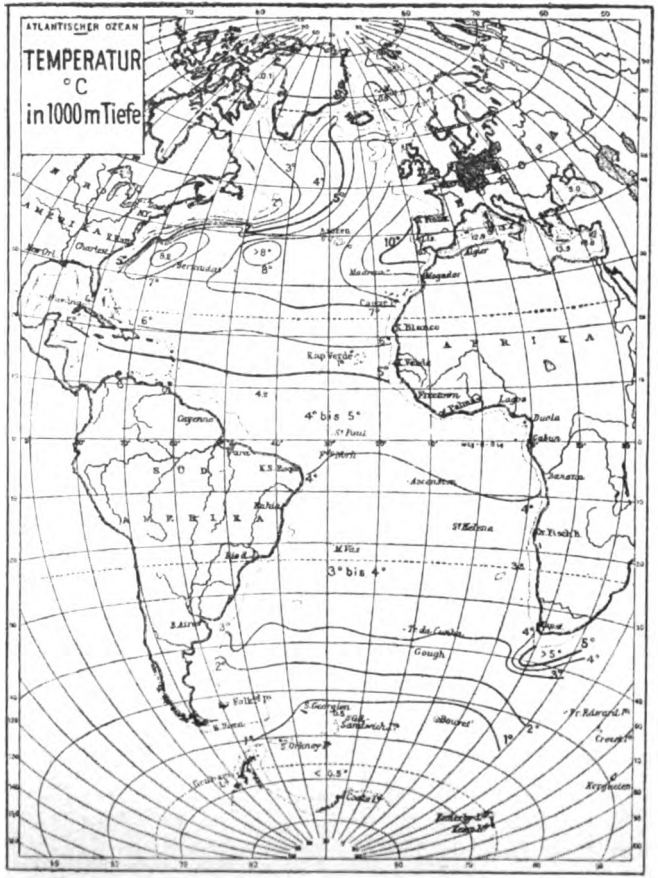


FIG. 3.—Temperature at a depth of 400 metres.



Temperature at a depth of 1,000 metres.

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is colder than Cape Horn. At 50° N. the temperature is about 10° higher than at 50° S., while cold patches will be noticed at 20° N. on the African coast, due to the cold water ascending from below as we have just seen.

In Chart III. we are shown the Centigrade temperatures at depths of 400 m. and 1,000 m. As we should expect, the water,

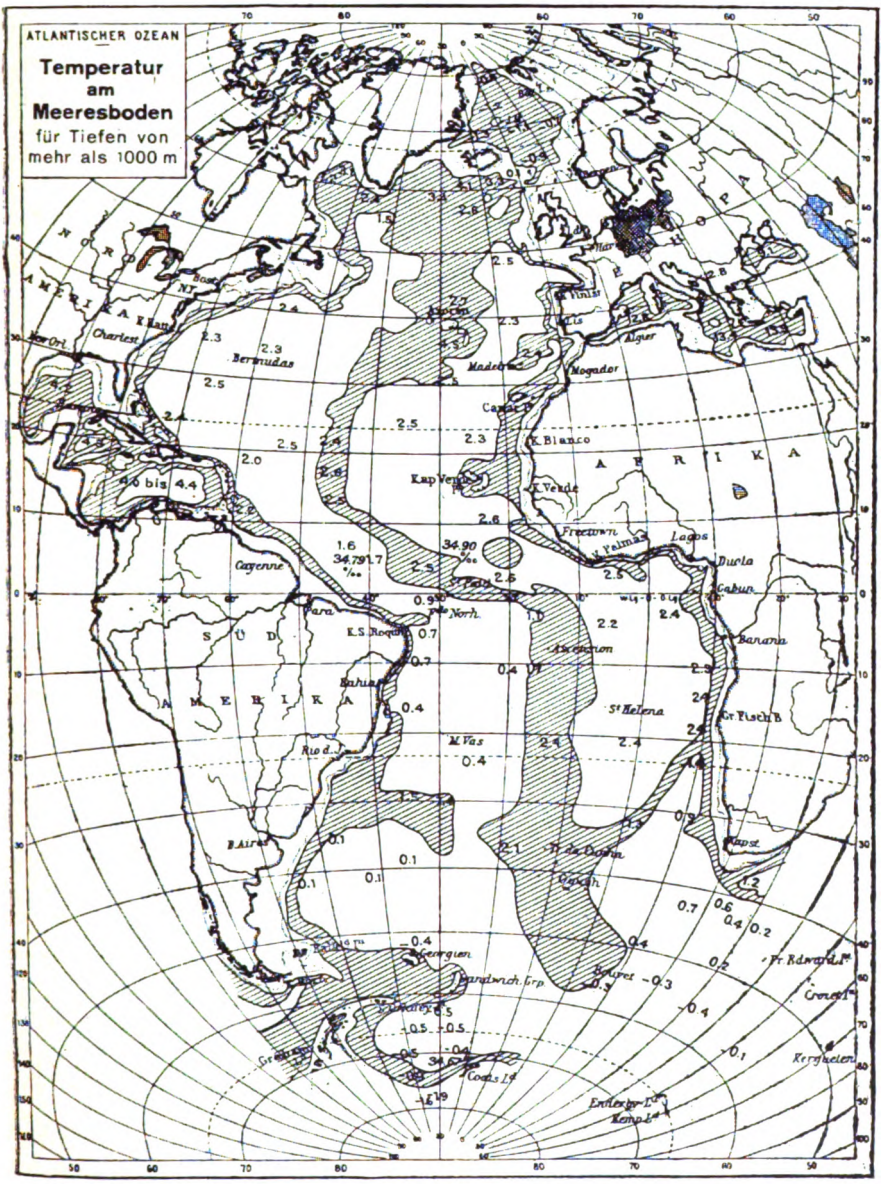

FIG. 4.—Temperature at the bottom of the ocean. The shaded areas represent depths of 1,000 to 4,000 metres; information for depths below 1,000 metres is not given.

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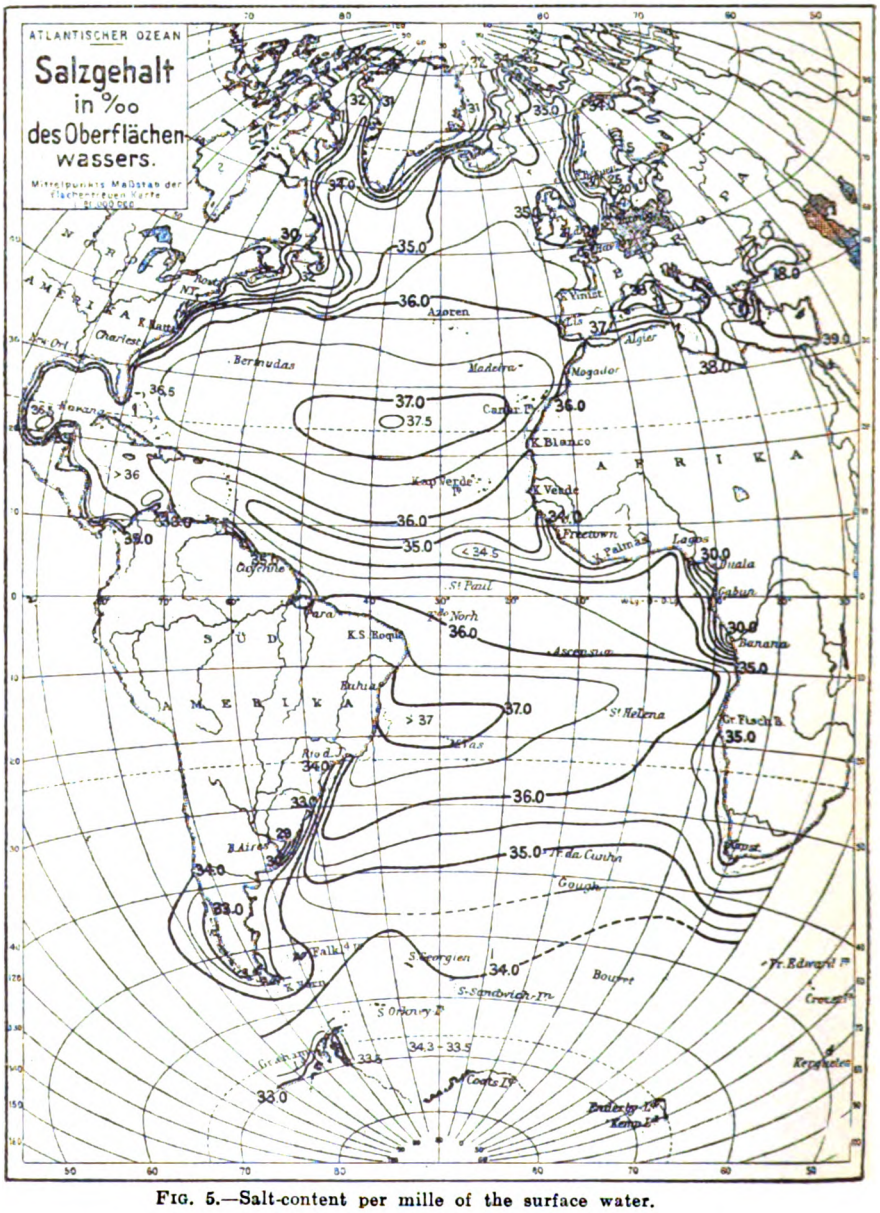
except in polar regions, gets colder as we descend. It is, however, only for a depth of about 100 m. that the water is warmest at the equator. At a depth of 400 m. near the Bermudas it is 9° warmer than at St. Paul on the equator. In the South Atlantic this feature is less marked. The explanation is both obvious and important, and it lies in the contrast between the descent of warm surface water and the welling up of cold water from the equatorial depths. It shows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Salzgehalt
in ‰
des Oberflächen-
wassers.
Mittelpunkts Maßstab der
flächentreuen Karte
1:100 000 000
NORD AMERIKA
SÜD AMERIKA
AFRIKA
Bermudas
Azoren
Madeira
Kap Verde
St Paul
St Helena
Ascension
Tristan da Cunha
Gough
Bouvet
Kerguelen
Charleston
Cayenne
Freetown
Lagos
Gabun
Banana
Buenos Aires
Rio de Janeiro
Bahia
Falkland Is.
S. Georgien
S. Sandwich-Is.
S. Orkney Is.
Graham Land
Coats Land
Enderby-Land
Kemp-Land
Prince Edward Is.
Crozet Is.
Agulhas
Walfisch B.
Fisch B.
Mogador
Algier
Canar. Is.
C. Blanco
C. Verde
Lüderitz B.
St. Paul Rocks
Fernando Noronha
Rocas
Trinidad
Para
Recife
Abrolhos
Rio de la Plata
Bahia Blanca
Port Stanley
Tristan da Cunha
Gough
Bouvet
Kerguelen

that although the trade winds blow towards the equator, the surface sea currents have, in general, a component away from the equator. At a depth of 1,000 metres the warm water of the Mediterranean flows out abundantly. This is because evaporation increases the salinity more than the inflow from rivers lessens it, and while the lighter water outside the Straits of Gibraltar flows into the Mediterranean near the surface, the heavier water within the Mediterranean escapes down below.

Among the most striking conditions are those of temperature at the sea bottom. Where the bottom is more than 1,000 m. below the surface its temperature is shown in Chart IV. Regions distinguished by shading are less than 4,000 m. deep, and an S-shaped ridge, flanked by deeper regions on each side, running N. and S. down the centre of the ocean may also be noticed. In the western trough the icy water of the antarctic starts at 0°.5 below zero; it flows north, as we shall see later, and rises to +1° at the equator and to 2°.5 below the Sargasso Sea. Into the eastern trough the antarctic water cannot flow freely owing to the ridge opposite Walfisch Bay and temperatures above 2° prevail into the Bay of Biscay. Fresh water is, of course, at its densest at a temperature of 4°C., but ordinary sea water is densest at about −2°, its freezing point.

Salt Content.

Turning now to the amount of brine in the water, and attention must be paid to this because variations in salinity have more effect on the density than variations in temperature—in other words, saltness under prevalent conditions makes the water heavier than coldness—we have in Chart V. the salt content in parts per thousand in the surface water. These are least in equatorial and in polar regions.

The next chart (Chart VI.) of salt content in parts per thousand at depths of 400 and 1,000 metres shows that salinity, like temperature, decreases with depth except in the polar regions and that the Atlantic Stream carries high salinity down to a depth of 1,000 metres right into the arctic seas. Also the outflow of the Mediterranean at the deeper level is apparent as conspicuously in salinity as in temperature.

Deep sea surveys have of late provided a considerable amount of information and from these Brennecke has prepared sections through the centre of the N. Atlantic and the west of the S. Atlantic. We observe in Chart VII., which shows a section extending from 81° N. to 78° S. and to a depth of 3,000 m., considerable similarity between the distributions of temperature and salinity, with some inversions at depths of a kilometre or more; the salinity also increases with depth in the topmost 100 metres in several areas near the equator. This is presumably due to the heavy rain and the small evaporation over this region, combined with the inflow of fresh water from the African rivers.

If we examine the 36 per thousand salt line we see a maximum at 25° N. down to a depth of 450 m. and at 20° S. down to a depth of 250 m.

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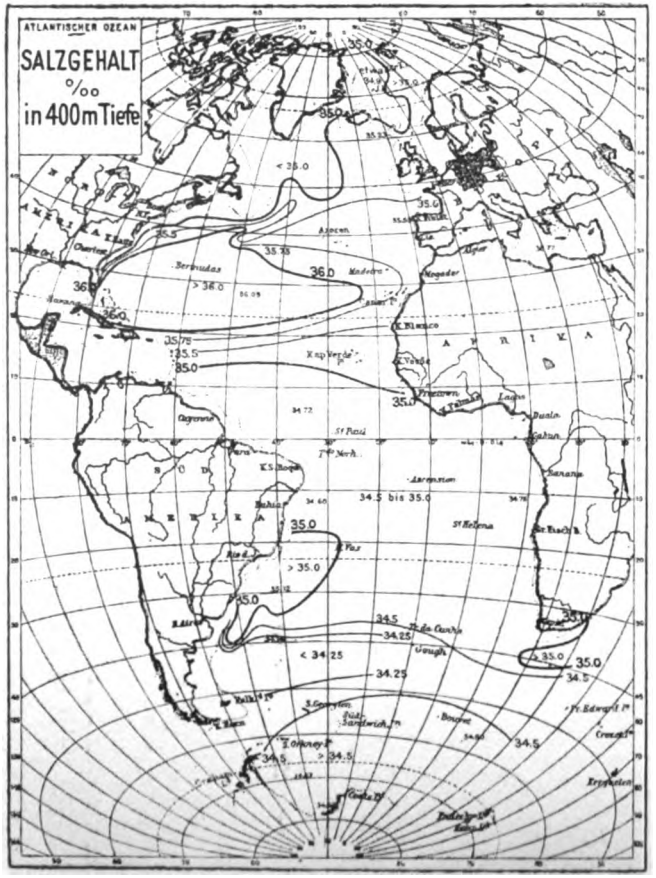
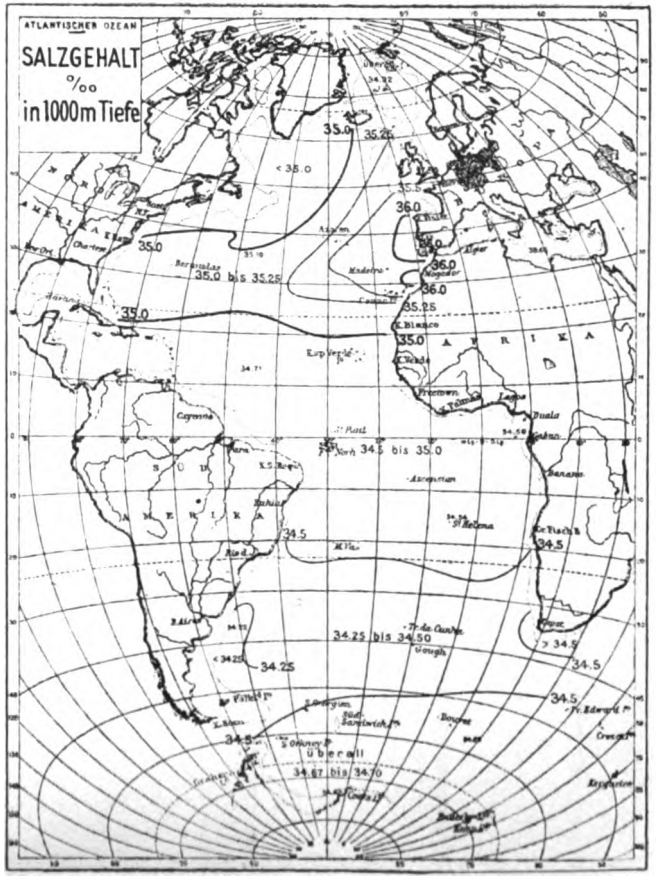


FIG. 6.—Salt-content at a depth of 400 metres.



Salt-content at a depth of 1000 metres.

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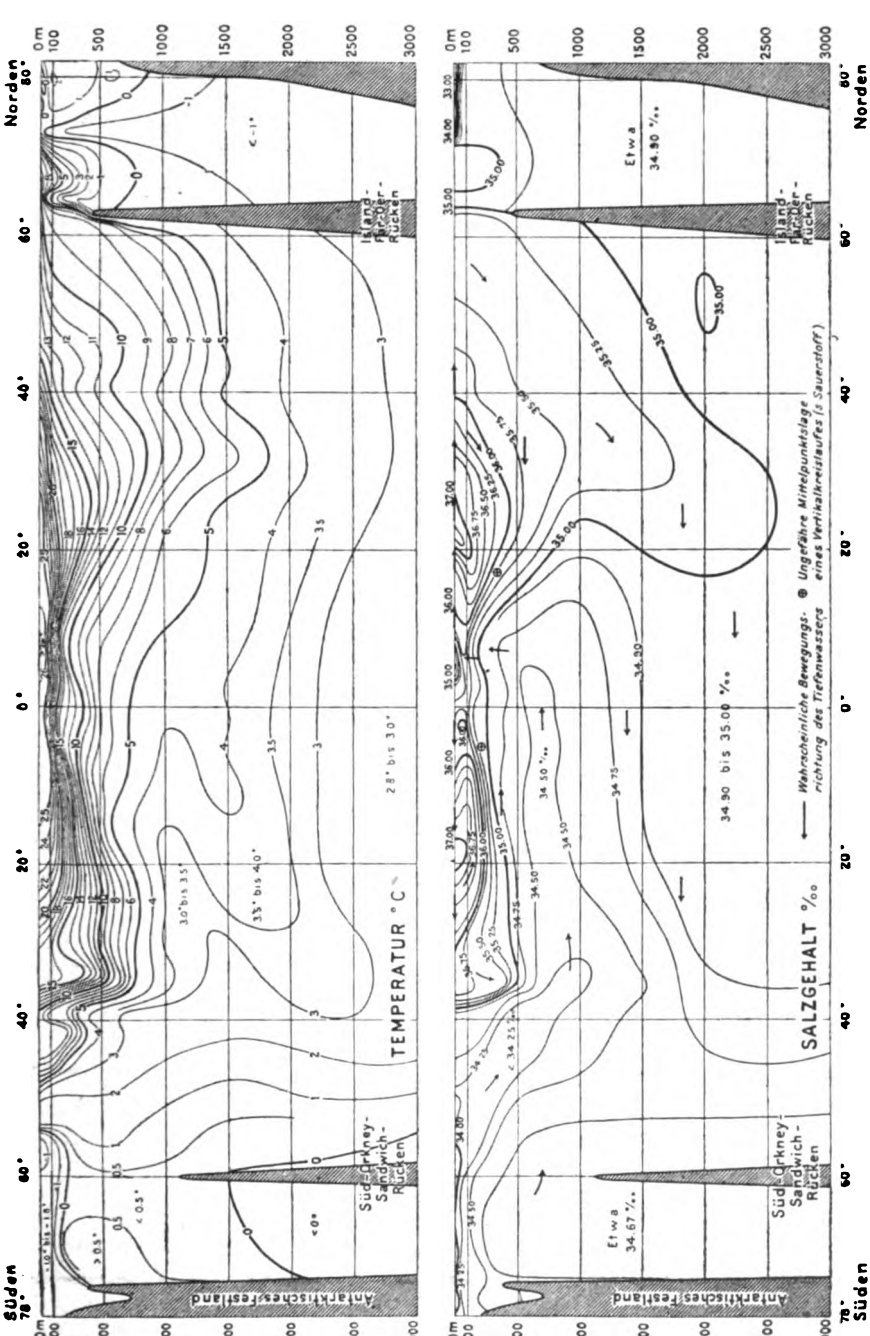

FIG. 7.—Sections through the centre of the N. Atlantic and the West of the S. Atlantic showing temperature and salt-content respectively

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The big tongue of water with a smaller salt content than 34.5 in southern latitudes, suggests that relatively fresh cold antarctic water has descended and has flowed in a horizontal stream northwards over the equator at a depth between 600 m. and 1,000 m. This minimum has been verified by observation in both the E. and W. deeps of the S. Atlantic and traced as far as 20° N. The evidence for this recent and important conclusion that flow from

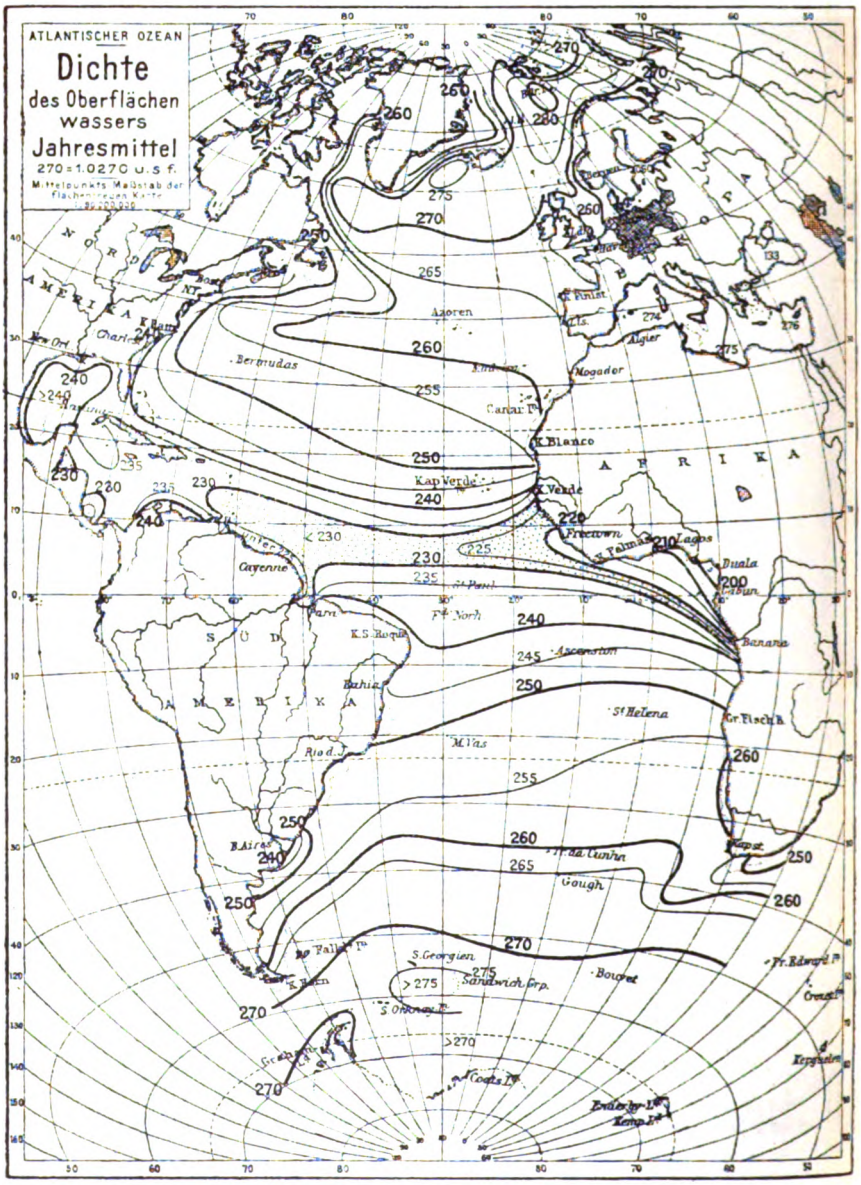

FIG. 8.—Yearly mean density of the surface water. 270=1.0270, etc.

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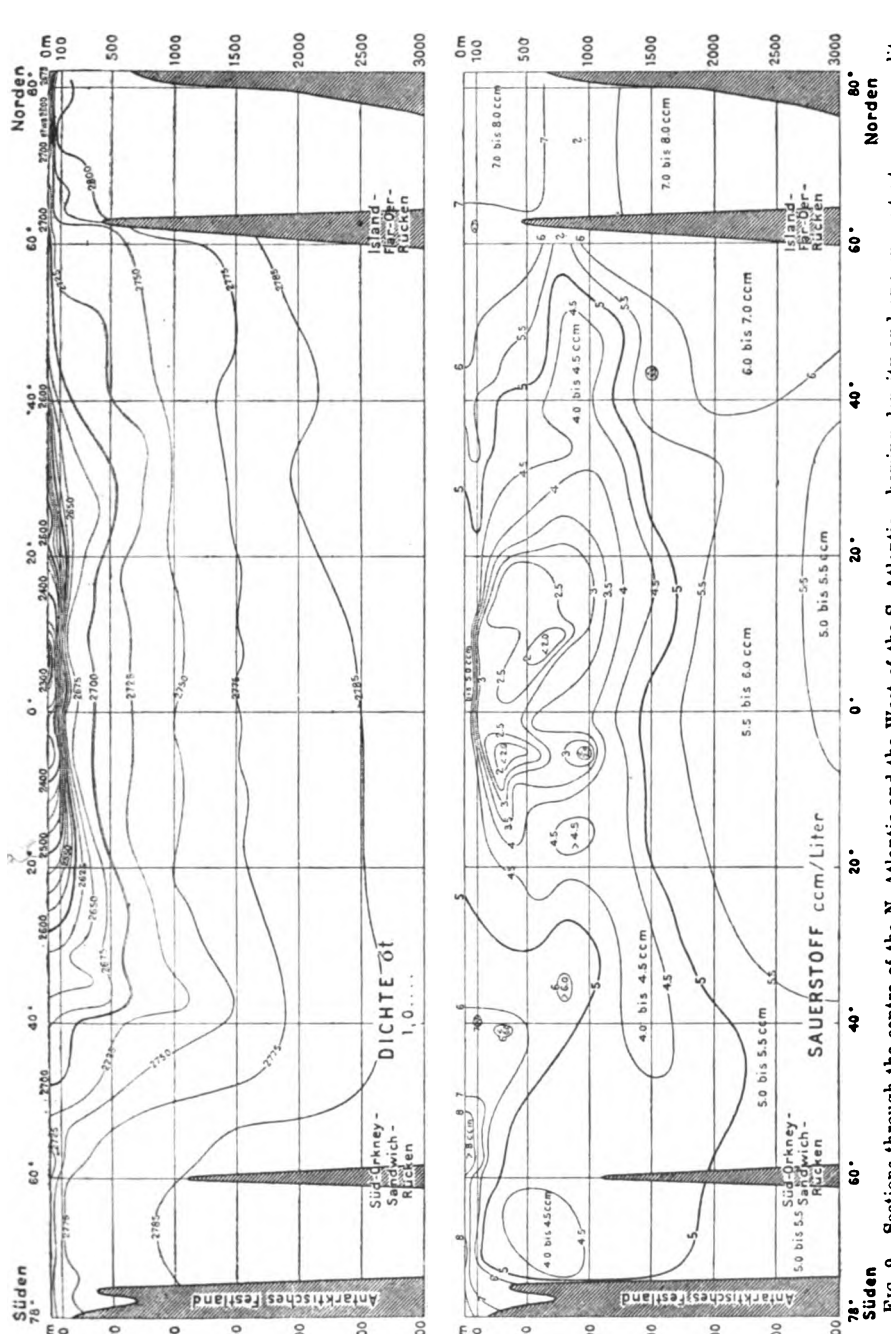

FIG. 9.—Sections through the centre of the N. Atlantic and the West of the S. Atlantic showing density and oxygen content, c.cm. per liter.

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the antarctic extends beyond the equator is supported by the temperature diagram which shows a corresponding minimum. It should, however, be remarked that although these currents afford the most natural explanation of the steady conditions, it is not clear that no other is possible.

The surfaces of equal pressure are needed for an effective discussion of the circulation and for these the mean annual density distribution is required. This, for the surface water, is shown in Chart VIII, where a number such as 255 means a density of 1.0255, etc. The water is lightest at the equator and gets denser as we approach 60° N. and 60° S. The lightest water occurs in the hot and very rainy region in the Gulf of Guinea, while the densest occurs near Bear I., where the briny water of the Atlantic drift has at length lost the heat with which it left the tropics and has, after a journey of 7,500 miles, assumed arctic coldness.

The association which we have remarked between warmth and saltness very greatly diminishes the variations of density and in the upper section of Chart IX. the density everywhere increases very slowly with depth. The conditions are therefore stable for displacements of small masses. A gallon of water if raised ten feet would be in water lighter than itself and would sink back again; but if a large volume is acted on by pressure differences there is nothing to prevent it from steadily moving at a rate so slow as not to disturb those pressure conditions.

The next chart (Chart X.) gives the lines of equal pressure calculated from the density diagram. These lines coincide so closely with the lines of equal depth that the vertical scale for pressures has to be 100 times the scale for depth before the form is suitably indicated. From 100 m. to 500 m. the gradients drive polar water

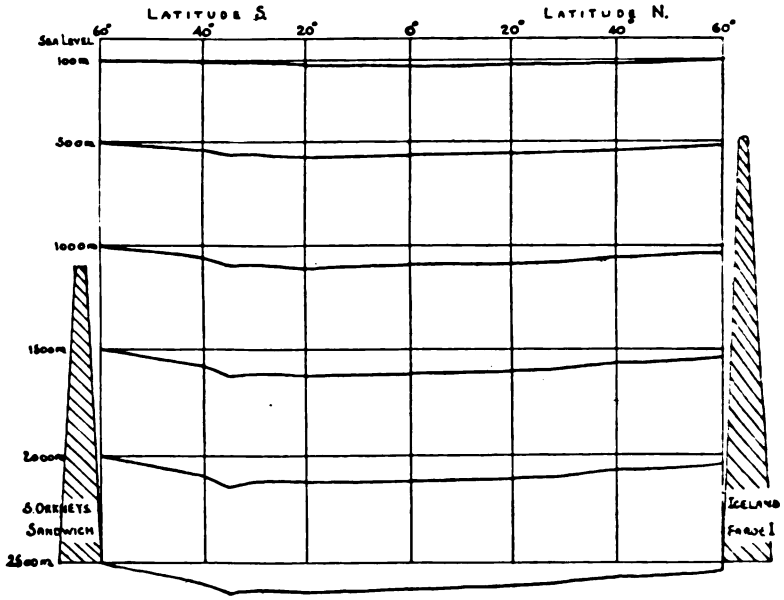

FIG. 10.—Section through the centre of the N. Atlantic and the West of the S. Atlantic showing surfaces of constant pressure.

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to the equator, and set up a very slow but nevertheless important downflow at latitudes 60° N. and S. with flow thence towards the equator, where an ascending current will be produced. At greater depths the conditions are roughly similar except that the water from the northern regions would tend to cross the equator to about 30° S., as indicated by the salinity diagram.

The ice-cellar of the Atlantic is the Weddell Sea, where there are enormous masses of pack-ice, *i.e.*, smashed up sea ice. The icebergs that break off from antarctic glaciers or from ice barriers play in this a relatively small part. The prevailing severity is shown by the very small number of times, four only, that the parallel of 75° S. has been crossed since Weddell penetrated in 1823. Not only is the great eastward current between latitudes 50° S. and 60° S. intensely cold, but it turns northwards under the influence of the earth's rotation, and is specially strong along the West African coast. Its chilling influence dominates the S. Atlantic below as well as on the surface. Thus while Cape Horn does not belong to the polar zone, Bouvet I. is covered with snow down to sea-level even in summer.

The Arctic Ocean, shown in Chart XI., is partly separated from the true Atlantic by a ridge generally less than 500 m. below sea-level and joining Greenland, Iceland, Faroe I. and the Shetlands; east of these islands the water is shallow. The polar ice, which normally covers about two-thirds of the surface, finds no outlet through the narrow and shallow Behring Straits; but on the other hand the Atlantic current, being salt as well as cold, sinks below the polar stream on meeting it and pours in considerable volume into the great polar basin. The conditions may be seen in Table I., where the lower Atlantic current may be recognised by its higher temperature and salinity. This inflow into the arctic basin is supplemented by large volumes of fresh water from a number of rivers and a big outflow is necessary before we can under-

TABLE I.—The Dipping of the Gulf Stream Under the Polar Stream in the Arctic Ocean. Direction of Stream, East to West (Summer).

Region.	East Greenland Stream. (Scoresby Sound.) 71° 21′N. 17° 25′ W.		East Iceland Stream between Iceland and Jan Mayen 69° 9′ N. 12° 0′ W.		Gulf Stream near the Lofoten Islands 69° 13′N. 10° 40′E.	
Ship	" Belgica."		" Michael Sars."		" Michael Sars."	
Date	16th August, 1905.		6th August, 1900.		13th August, 1900.	
Depth (metres).	Temp. Deg. C.	Salinity. Grams per kgr. of water.	Temp. Deg. C.	Salinity Grams per kgr. of water.	Temp. Deg. C.	Salinity. Grams per kgr. of water.
0	−0.7	30.60	5.7	34.24	10.4	34.58
50	−1.7	34.22	−1.4	.57	8.0	35.13
100	−1.7	.31	−1.0	.72	5.6	.17
150	−0.2	.50	0.0	.85	5.0	.15
200	+1.1	.86	0.6	.95	4.6	.15
400	0.8	.89	0.3	.96	3.7	.11
600	0.2	.93	—	—	3.7	.09
800	−0.2	.92	—	—	1.6	34.99
1,000	—	—	−0.7	.97	−0.1	.94
Bottom	−1.0	.92	−1.0	.95	−1.0	.93
Depth (metres)	1,400		1,500		3,100	

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stand the drift of the Fram which, in 1893, left the New Siberian Islands and by 1896 had drifted nearly as far as Spitzbergen. The polar water just north of the Iceland-Shetland ridge is of icy

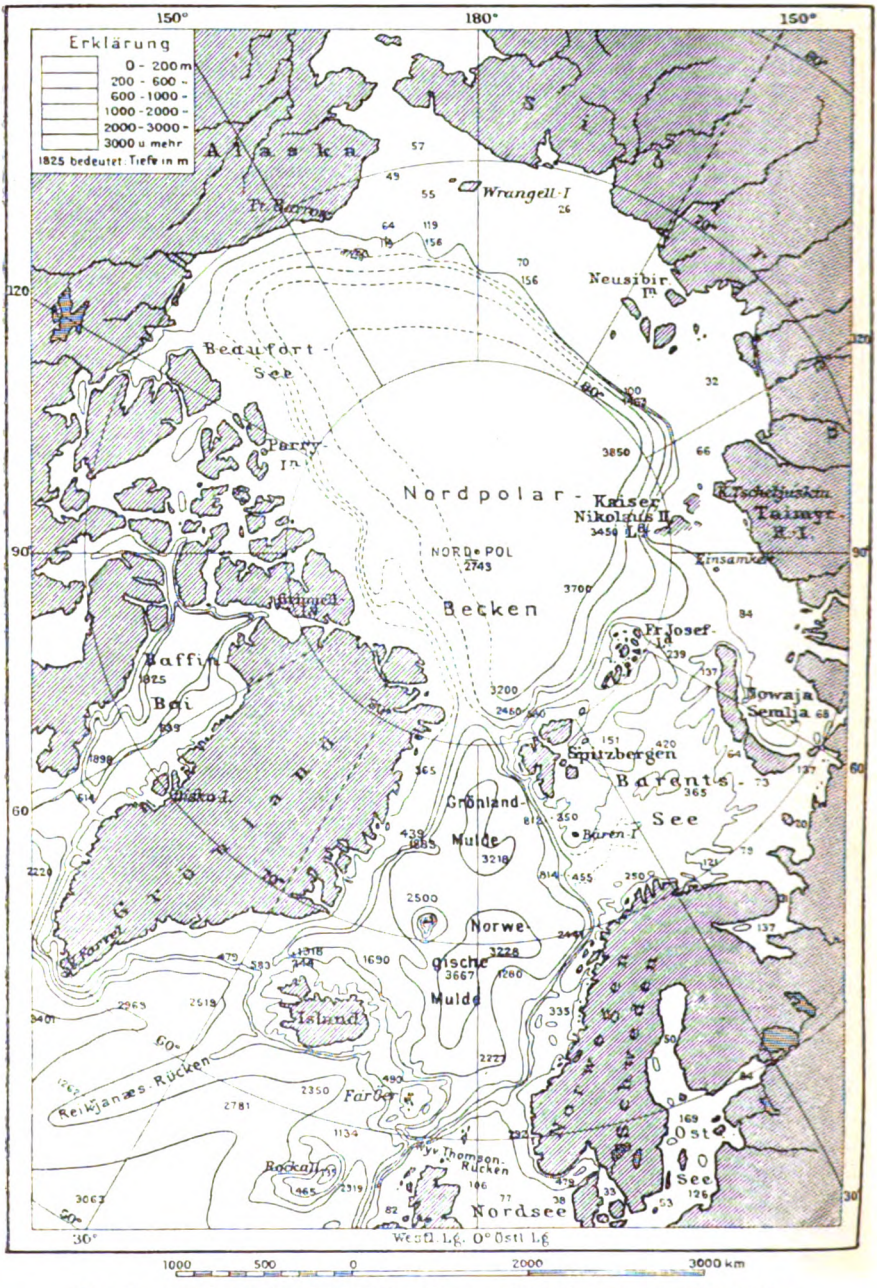

FIG. 11.—Depth of the North Polar Basin and of the European North Sea.

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coldness at depths below 400 metres, and the surplus water of the Arctic flows over this ridge as over a weir into the warm Atlantic water on the south side. On the whole, therefore, we may regard the Arctic as an arm of the Atlantic.

I will conclude with some general remarks:—(*a*) Although differences of salt content have more effect on density than differences of temperature, the motive power of the circulation lies in the differences of heat radiation between the tropical and polar regions.

(*b*) We know of nothing in the ocean corresponding to our short-lived cyclones and anticyclones. But, as we should expect, the general character of the oceanic circulation in winter roughly resembles that of the atmosphere at that time, as shown in Chart XII. The differences are mainly due to the definite land boundaries of the ocean and the condition that the outflow at the top of an ascending column of sea water will correspond to an inflow associated with an ascending column of air observed at ground level. Thus to N.E. trades in the air will correspond S.E. surface currents in the water.

(*c*) When the air and sea have different temperatures it is that of the air which approximates to that of the sea, not *vice versa*; variations in sea currents therefore have marked influence on weather.

(*d*) Regarding the extent to which prevailing winds control the general sea currents there is still much controversy. The distribution of temperature indicates clearly that the surface winds have little or no effect at a depth of 200 metres; and inasmuch as the general circulation of the ocean extends to depths of over 3,000 metres, it would appear that widespread differences of density, not surface winds, provide the greater part of the motive power for that circulation. Even the surface currents do not appear to be adequately explained in terms of winds alone. If we compare Charts I. and XII. we see the strongest winds in the Atlantic are those from south of Newfoundland to the south-east of Iceland, and in this open region the sea currents in the direction of the wind weaken to less than six sea miles in 24 hours. On the other hand, in the region between 0° and 20° W. longitude and 5° N. and 5° S. latitude we have calms and light winds, yet the sea currents vary between a westward stream exceeding 12 miles and an eastward one exceeding 24 miles.

(*e*) The effects within the topmost 100 or 200 m. are, however, vital in the control of air temperature; and it seems likely that the temperature effects in N. Europe produced by previous variations in the Atlantic trade winds are due to this control.

(*f*) As far as seasonal variations are concerned there is abundant evidence of the importance of knowledge of ocean conditions. Thus in the very place where the Swedish expedition vessel "Antarctic" was compressed by the ice in the summer of 1903 an Argentine lightly built vessel moved unhindered in the following spring, meeting no ice; accordingly the northern ice limit in the antarctic may sway backwards and forwards over 1,500 km. or nearly 1,000 miles. Similar changes occur in arctic regions where the limit of ice may travel many hundreds of miles in an east-west

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direction. Thus 1892 was comparatively free while 1882 was badly icebound.

Now the most striking relations between seasonal variations are those in what I have elsewhere called the "southern oscillation"; and in that perhaps a half of the effects occur after a lag of three or six months. It may be that a few of these may be

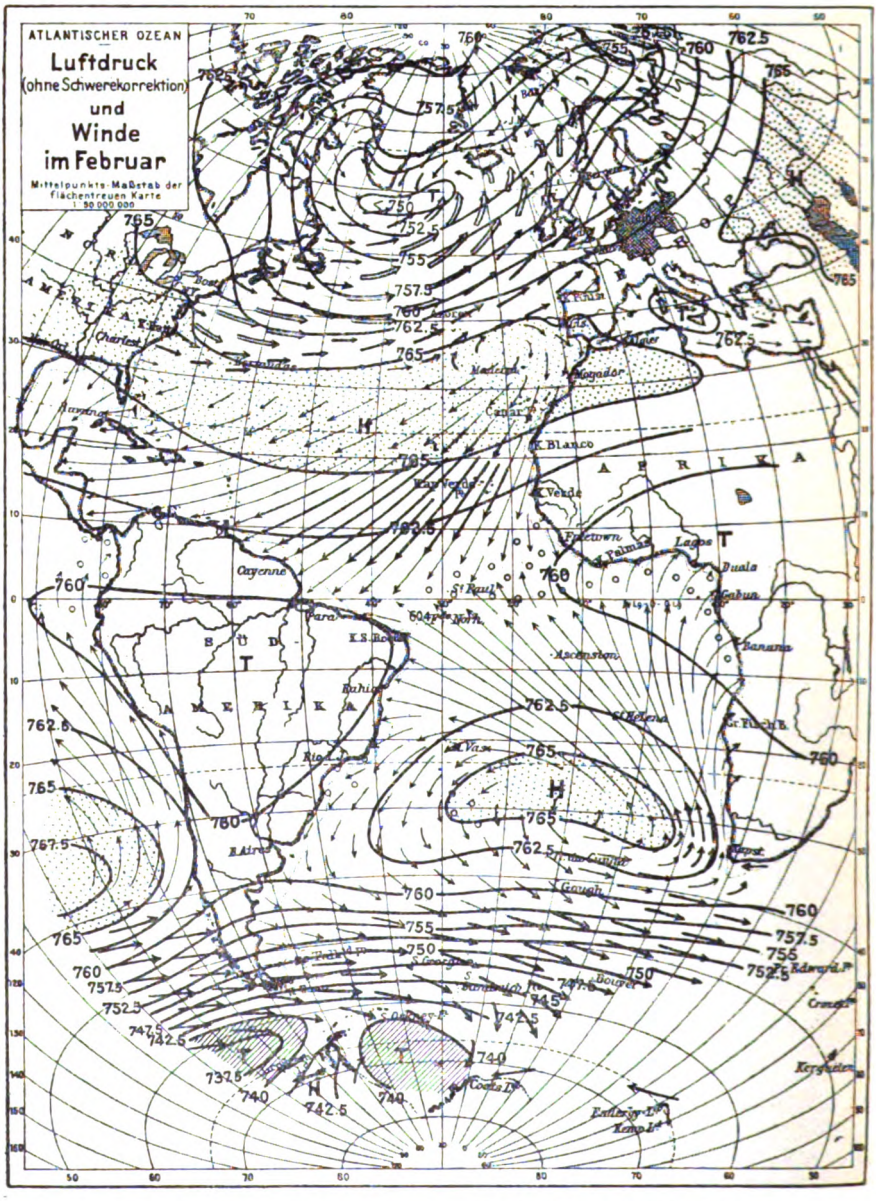

FIG. 12.—Pressure (without gravity correction) and winds in February.

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explained by the variations in temperature of a local current that spends some months in passing from the controlling to the controlled station; but variations in activity of the general oceanic circulation will be much more far reaching and important. An abnormally severe season in the Antarctic may produce colder currents in the ocean deeps as well as at the surface, and when this water rises to the surface near the equator it may affect temperatures there many months afterwards. As evidence of the impor-

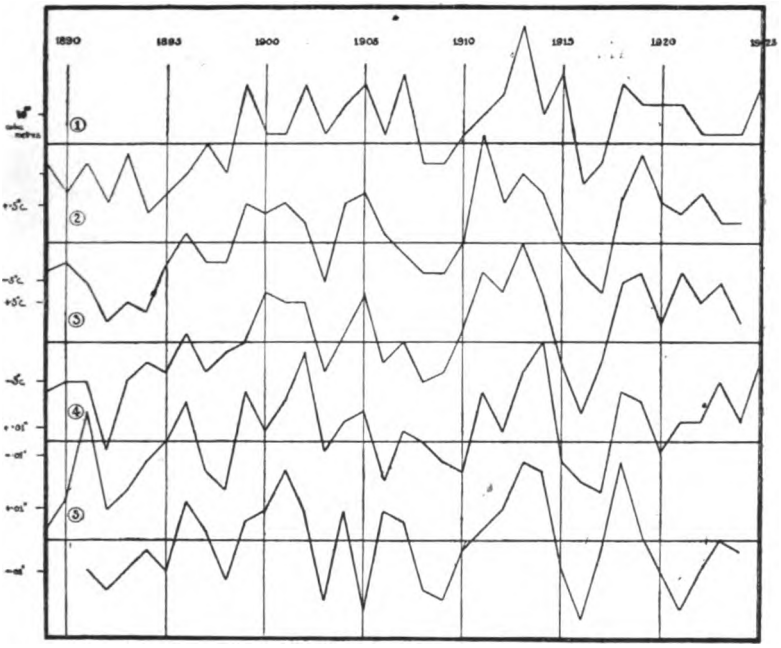

FIG. 13.—Chart showing the successive values from 1889 of the departures from normal of (1) Nile floods, July to October, reversed; (2) Samoa temperature, December to February, afterwards; (3) Samoa temperature, March to May, three months later; (4) Port Darwin pressure, September to November, six months before curve (3); (5) Zanzibar pressure, December to February, three months before curve (3).

tance of equatorial temperatures we may refer to Chart XIII. in which a comparison of curves 2 and 3 will indicate the persistency of the temperature of Samoa from summer to autumn; and the similarity of these to curve 1, showing the character of the Nile flood for the previous season, shows the far-reaching character of these effects. As will be seen from curves 4 and 5 powerful influences extend as far as Port Darwin in Australia and to Zanzibar.

If my words have not prevented these diagrams from telling their own story, you will recognize that oceanography is a most interesting as well as an important study.

[The Society is indebted to Dr. Gerhard Schott and to the publishers for permission to reproduce in monochrome and on a reduced scale the diagrams illustrating this address. They are taken from *Geographie des Atlantisches Ozeans*, second edition, revised and enlarged. Hamburg (C. Boysen), 1926.]

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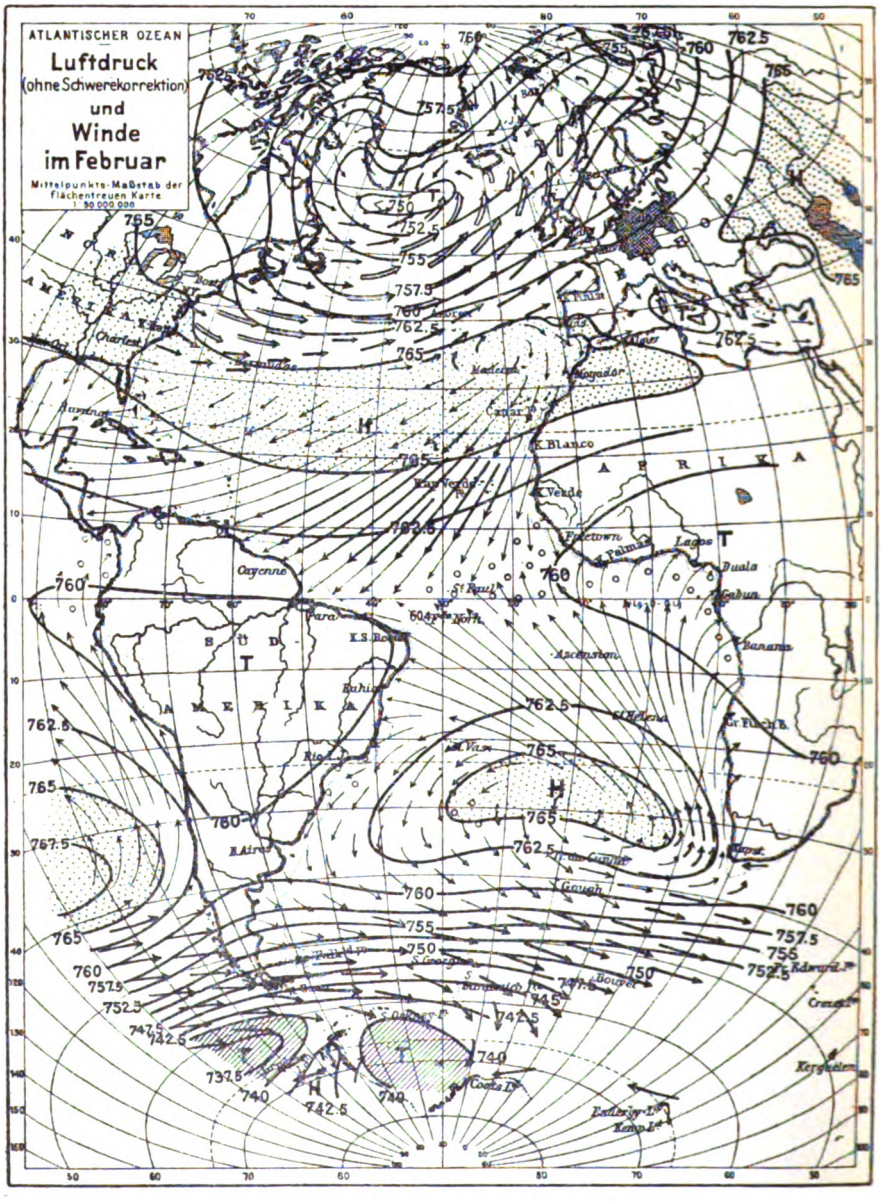

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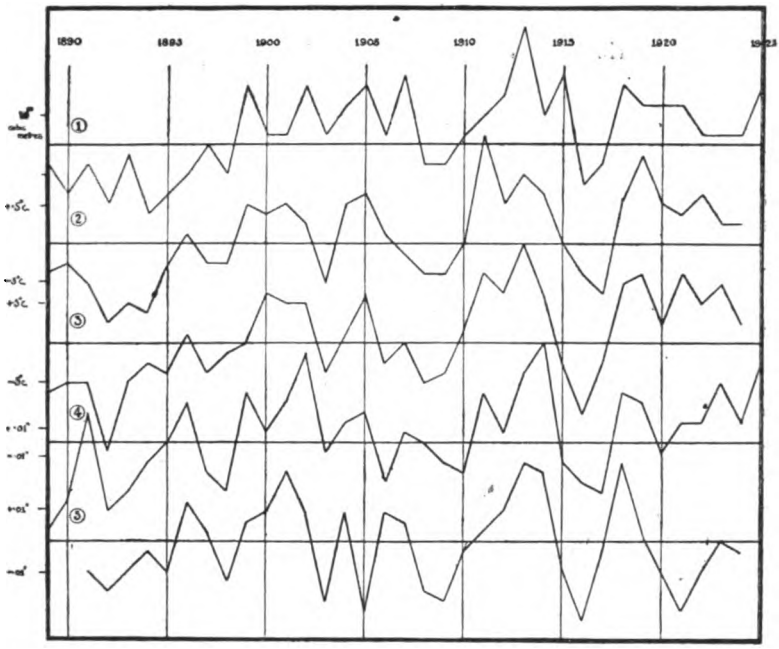

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The Adams Prize.

Dr. Harold Jeffreys has been awarded the Adams Prize for the period 1925-26 for an essay on "The Constitution of the Interior of the Earth, and the Propagation of Waves through the Interior and over the Surface of the Earth." The prize is awarded by the University of Cambridge every two years for an essay on some branch of pure mathematics, astronomy, or other branch of natural philosophy, and is of the value of about £250.

Report of Curious Sunset off North Coast of Java, Feb. 13th, 1927.

In lat. 6° 26′ S., long. 108° 51′ E., on Sunday, February 13, while leaving the port of Tegal, a very curious phenomenon was observed in connection with the sunset.

Over to the westward were the high ranges of mountains of Western Java, covered with a thick layer of nimbus and cumulo-nimbus clouds, behind which the sun had dipped, and they appeared, in the fading light, a dark grey except for the tops, which were tinted a deep, golden colour. Above these, and only in the region of the sun—that is, to the western quarter of the sky—was a smooth mass of light "clouds," greatly resembling cirrus-stratus, of an orange yellow colour.

FIG. 1.—Curious cloud shadow cast by Cu.-Nb.

A clear-cut shadow was cast by the apex of the nimbus clouds across the layer of light "clouds," totally obliterating those actually in its path. That is to say, through the shadow the clear, dark-blue sky was visible. The accompanying diagram will make my description plainer, I believe.

The conclusion arrived at was that the orange yellow mass was not clouds, but a mass of dust particles suspended over the land, and when the rays of the setting sun shone on them obliquely *underneath*, their presence was manifested by a seeming layer of light cirrus-stratus clouds. Where the direct rays of the sun were shut out, the dust particles had no reflected light beneath them and so became invisible to the eye.

As the sun gradually sank, the shadow became less obvious, until with the actual setting of the sun it disappeared altogether, and an unbroken layer of clouds was left.

H. MAGUIRE (3rd Officer).

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INVESTIGATIONS ON THE BEHAVIOUR OF HYGROMETRIC HAIRS.

By AMAR NATH PURI, Ph.D.,

Soil Physics Department, Rothamsted Experimental Station, Harpenden.

[Manuscript received in revised form October 28—Read December 15, 1926.]

INTRODUCTION.

The use of the hair hygrometer as a practical instrument for measuring the humidity of the atmosphere has long been recognised. For a review of the older literature and a discussion of the theory of the hair hygrometer the reader is referred to a paper by F. J. W. Whipple.[1]

Recently, E. Griffiths[2] has examined a few types of hair hygrometer in which the necessary magnification of the extension of the hair is obtained by the ordinary system of lever attached to a pointer moving over a graduated dial. One serious disadvantage of such instruments is that there is uneven loading on the hair, depending on whether the latter is contracted or extended. Further, such instruments are liable to show considerable lag due to friction in bearings and pivots. Griffiths arrives at the conclusion that under normal working conditions the hair hygrometer shows a tendency to give high readings with lapse of time. This is ascribed to the fact that the hairs are always under tension and consequently a permanent set takes place.

The object of the present work is to study the behaviour, when subjected to a series of humidity changes controlled by means of suitable sulphuric acid-water mixtures over a fairly long period, of hair hygrometers of the type in which the total load on the hairs consists of a weight.

SECTION I.

Description of Instruments.

Four instruments were studied. The first was examined independently and the remaining three simultaneously.

TYPE A (see Fig. 1).

A hair 10.5 cm. long was mounted horizontally close to the underside of a sheet of plate glass by means of two hooks. The hair was fixed to one hook, passed over the other, and carried a 2 grm. weight to maintain constant tension. The glass plate rested on the top of a rectangular glass vessel, thus enclosing the hair in an atmosphere the humidity of which was controlled by placing sulphuric acid-water mixtures of known strength inside the vessel. By means of a small knot previously tied in the hair, and a fixed reference line, the extension could be accurately measured with a micrometer eye-piece. Equilibrium was attained in about half an hour, though in practice the hygrometer was kept at one humidity from 8-12 hours.

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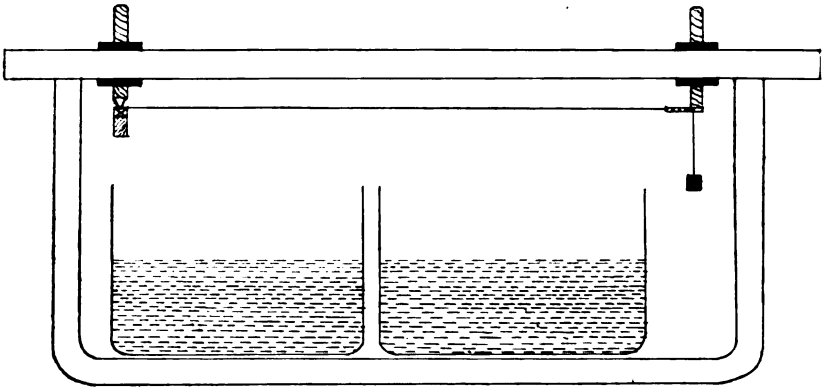

FIG. 1.—Hair Hygrometer. Type A.

TYPE B.

In this instrument a hair 72 cm. long was mounted vertically in a glass tube of 0.5 cm. bore. To the lower end was attached an ordinary sewing needle, 0.15 gm. in weight. Measurements of the extension of the hair were taken by a vertical travelling microscope with a vernier scale reading to .01 mm. The stream of air was brought to the desired humidity by passing it through a series of five bottles containing a sulphuric acid-water mixture. It then passed through the tube containing the hair.

TYPE C.

This instrument was essentially similar to B, but instead of the glass tube a Charlottenburg burette was employed. The weight was a small aluminium tube (.85 grm.) and readings of the extension of the hair (68 cm. long) were taken against the graduations on the burette tube.

TYPE D.

This was a commercial pattern known as Negretti and Zambra's Improved Hygroscope. The hairs (which number 12 or more), forming a single cord, are anchored at the lower ends to an adjustment of special design, and the other ends are connected to a link which operates on a lever attached to the pointer spindle. The total load on the hairs consists of a weight of about 4 gms. The dial is graduated from 10 to 100 giving directly the percentage humidity. The instrument was enclosed in a glass cylinder and the humidity controlled by passing an air current as described above. The general arrangement of the apparatus for types B, C and D is shown in Fig. 2.

THE EXPERIMENTS.

The various instruments were subjected to a series of dryings and wettings, the object being to see how far the readings at various humidities are reproducible.

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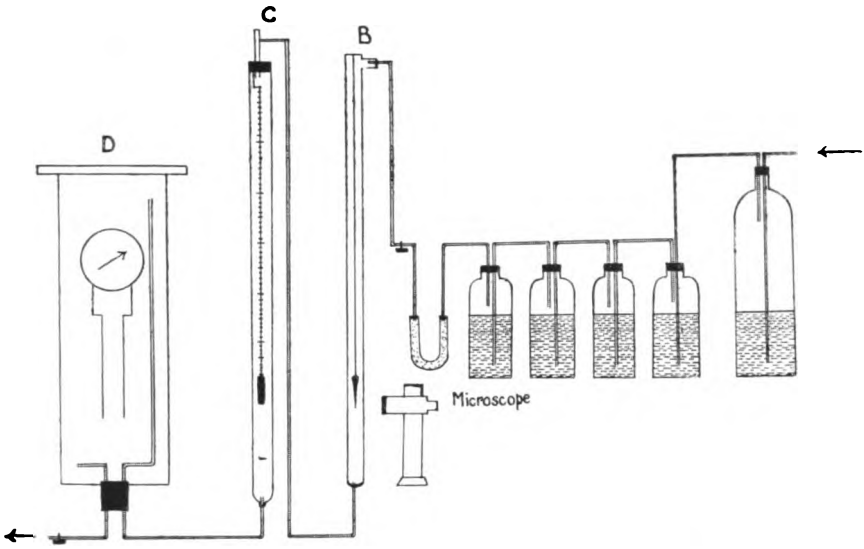

FIG. 2.—Arrangement of Apparatus for Hair Hygrometers. Types B C and D.

In the case of Type A instrument the process of drying and wetting was repeated five times during the course of a month. The other instruments were subjected to a more rigorous examination and the process was repeated 20-30 times. Table 1 gives the readings of the extension of the hair in the instrument A at different humidities in terms of the arbitrary micrometer scale (magnification 1 : 35). The course of the experiment is indicated by the arrows and it will be observed that apart from contraction and extension due to drying and wetting the length of the hair is gradually

TABLE I.—HYGROMETER A. READINGS ON THE MICROMETER EYE-PIECE AT VARIOUS HUMIDITIES.

Humidity.	Micrometer Readings.										
%	%	%	%	%	%	%	%	%	%	%	%
0	0	0 ↓	...	...	...	...	...	...	...	...	...
1.4	0.43	0.19	1.72	↓	3.42	↓	3.51 ↑	↓	3.72 ↑	↓	3.87 ↑
9.8	0.80	0.92	2.24	2.54	3.90	4.19					
19.5	1.23	1.79	2.62	3.28	...	...	...	4.95 ↓	↑	5.24 ↓	↑
41.2	2.33	3.05	3.08	4.51	4.92	...	...	...	...	...	...
70.3	3.15	3.93	3.97	5.58	5.67 ↑	...	...	...	...	...	...
88.5	3.42	4.51	4.42 ↑	6.06	↑	...	...	...	...	...	...
97.7	4.29 ↑	5.65	↑	...	...	...	...	...	...	...	...

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increasing. It appears, however, that this increase in length is regular and goes on at a constant rate in spite of the changes in humidities to which the instrument is subjected. This point will become clearer from Fig. 3, where the readings for various humidities are plotted against time and show the gradual increase in length during the whole period. The regularity of this stretch under strain also shows that the extension and contraction of a stretched hair due to changes in humidity follow the same law as that of an unstretched one.

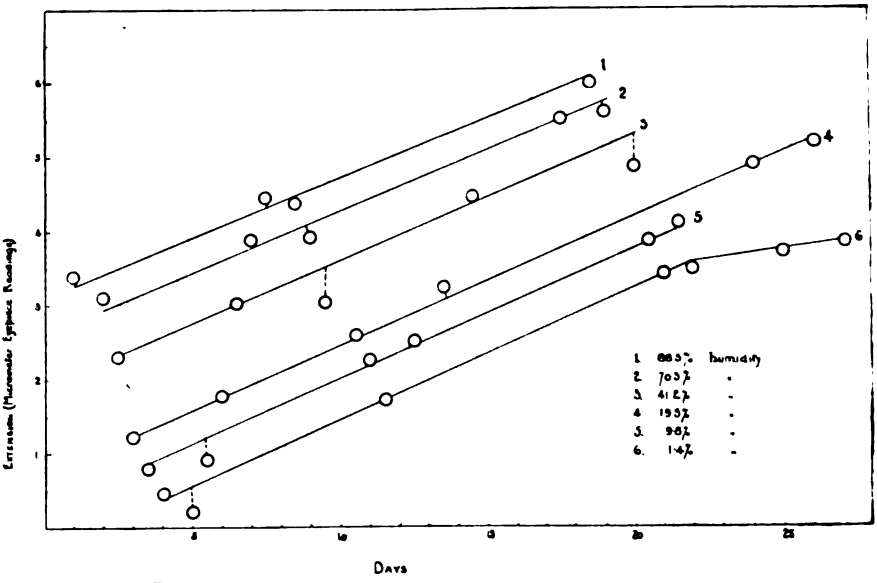

FIG. 3.—Extension of Hair under Constant Tension with Changing Humidity.

An examination of the results obtained with the other instruments (Tables II., III. and IV.) brings out the interesting fact that when the load is small this tendency to take up a permanent stretch is removed. Further, the instruments B and C both show appreciable hysteresis* at humidities 40.4 per cent. and 69.5 per cent., although the instrument D apparently does not show any such effect. The hysteresis becomes inappreciable when the instruments have been in use for about two months. It is very curious that the effect is in the direction contrary to all previous experience with colloidal material possessing a capillary or gel structure. For instance, it has been invariably found that the moisture content of an absorbent corresponding to a particular humidity is always less when equilibrium has been approached from the drier state than when it is attained from the wetter one, and if the exension of the hair is dependent on its moisture content

* There is a certain variation in the results of the successive determinations. These are attributable to unavoidable experimental errors in measuring the small extensions. The data were kindly examined by Mr. R. A. Fisher by statistical methods and the hysteresis effect shown to be significant.

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TABLE II.—Hygrometer B. Micrometer scale readings at various humidities. (0.1 division = 1 mm.)

HUMIDITY.							
89.5 Per cent.	69.5 Per cent.		40.4 Per cent.		19.5 Per cent.		10.4 Per cent.
Wetting.	Drying.	Wetting.	Drying.	Wetting.	Drying.	Wetting.	Drying.
3.11	2.92	2.99	2.63	2.70	2.38	2.43	2.29
3.13	2.93	2.99	2.63	2.68	2.39	2.38	2.23
3.14	2.95	3.00	2.63	2.68	2.38	2.38	2.23
3.12	2.91	2.99	2.65	2.70	2.41	2.37	2.23
3.14	2.93	2.99	2.63	2.69	2.38	2.41	2.20
3.12	2.94	2.96	2.62	2.65	2.38	2.36	2.24
3.15	2.94	2.97	2.66	2.66	2.40	2.38	2.20
3.14	2.98	2.98	2.63	2.64	2.39	2.39	2.22
3.11	3.00	2.98	2.64	2.67	2.39	2.38	2.23
3.12	2.96	2.99	2.65	2.67	2.40	2.39	2.23
3.14	2.95	2.99	2.64	2.65	2.40	2.39	2.24
3.14	2.96	2.98	2.65	2.65	2.41	2.40	2.24
3.14	...	2.99	2.65	2.66	2.40	2.39	2.26
3.15	...	3.00	2.65	2.66	2.40	...	2.26
3.14	...	3.00	2.65	2.66	2.39	...	...
3.14	...	2.99	...	2.65	...	...	...
3.14	...	2.99	...	2.65	...	...	...
3.13	...	...	...	...	...	...	...

TABLE III.—Hygrometer C. Burette scale readings at various humidities. (0.1 division = 1 mm.)

HUMIDITY.							
Wetting.	69.5 Per cent.		40.4 Per cent.		19.5 Per cent.		10.4 Per cent.
89.5 Per cent.	Drying.	Wetting.	Drying.	Wetting.	Drying.	Wetting.	Drying.
7.18	7.02	7.08	6.78	6.80	6.60	6.52	6.41
7.18	7.00	7.03	6.72	6.79	6.56	6.50	6.39
7.19	7.00	7.04	6.73	6.79	6.51	6.52	6.40
7.19	7.01	7.03	6.78	6.80	6.51	6.52	6.40
7.19	7.00	7.03	6.74	6.79	6.50	6.50	6.42
7.18	6.99	7.09	6.74	6.81	6.54	6.50	6.41
7.18	7.01	7.08	6.71	6.80	6.51	6.50	6.39
7.17	7.01	7.01	6.73	6.75	6.52	6.51	6.38
7.18	7.01	7.01	6.75	6.78	6.50	6.50	9.38
7.17	7.01	7.01	6.73	6.73	6.51	6.51	6.39
7.18	7.01	7.01	6.72	6.78	6.51	6.51	6.39
7.19	7.01	7.01	6.73	6.77	6.51	6.51	6.39
7.18	7.01	7.00	6.73	6.73	6.51	6.51	6.39
7.19	...	7.02	6.74	6.75	6.51	...	6.40
7.19	...	7.01	6.74	6.73	6.51	...	6.41
7.18	...	7.02	6.74	6.75	6.51	...	6.40
...	...	7.01	...	6.74	6.51	...	...
—	...	7.02	...	6.74	6.51	...	...
...	...	...	...	...	6.50	...	...

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TABLE IV.—Hygrometer D. Readings on the dial at various humidities.

HUMIDITY.							
89.5 Per cent.	69.5 Per cent.		40.4 Per cent.		19.5 Per cent.		10.4 Per cent.
Wetting.	Drying.	Wetting.	Drying.	Wetting.	Drying.	Wetting.	Drying.
90	73	72	44.5	42.5	24	25.5	15
90	71	73	39.8	41.5	23	21.5	13
90.5	72.5	73.5	40.5	42	24	21	14
90	70	73	42	44.5	25	21.5	14.5
95	72.5	73	40	41	25	20	15
86	73	75	41	42	24	20	17
85	72.5	72	43.5	43	22.5	21	12
88.5	71	71	41	43	23	...	13
91	...	72	40	40	25	...	14
94	...	73	...	42	23	...	...
94	...	71	...	40	24	...	...
...	...	...	...	43	...	...	...
...	...	...	...	42	...	...	...
...	...	...	...	40	...	...	...

one would expect that the extension would be greater when the hair was drying than when it was taking up moisture. On the contrary when the hair is taking up moisture it extends farther than the mean position. The action seems to be analogous to the swinging backward and forward to a mean position of a stretched spring or elastic string suddenly released. In practice, for a single-hair hygrometer, until the instrument ceased to show any hysteresis, it would be necessary to apply a positive correction to readings when the humidity is falling, and a negative correction when the humidity is rising.

The instrument D does not show this effect, probably on account of the inherent lag in taking up an equilibrium position due possibly to the slight friction in the lever mechanism used for recording purposes.

The readings of the various instruments have been recorded on a more or less arbitrary scale. In order to afford comparison between them the increase in length in the internal 10.4 per cent. to 89.5 per cent. humidity has been given below, expressed as percentages of the length of the hairs in the various instruments A = 0.79 per cent. B = 1.25 per cent. C = 1.15 per cent. D = 1.04 per cent.

A correction was applied to the readings of the instrument A to eliminate the effect of slow elongation due to strain on the hair.

For the purpose of affording comparison with the well-known theory that the contraction is proportional to the logarithm of the inverse of the relative humidity, the readings in the last complete line of Tables II. and III. have been plotted against the logarithm of the relative humidity, and are shown in Fig. 4. The readings of hygrometers A and D are not brought into Fig. 4 because the former shows slow elongation which overlaps the effect of extension due to a change in humidity, and the latter gives direct readings

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of humidity which are difficult to translate in terms of extension without introducing appreciable errors of measurement.

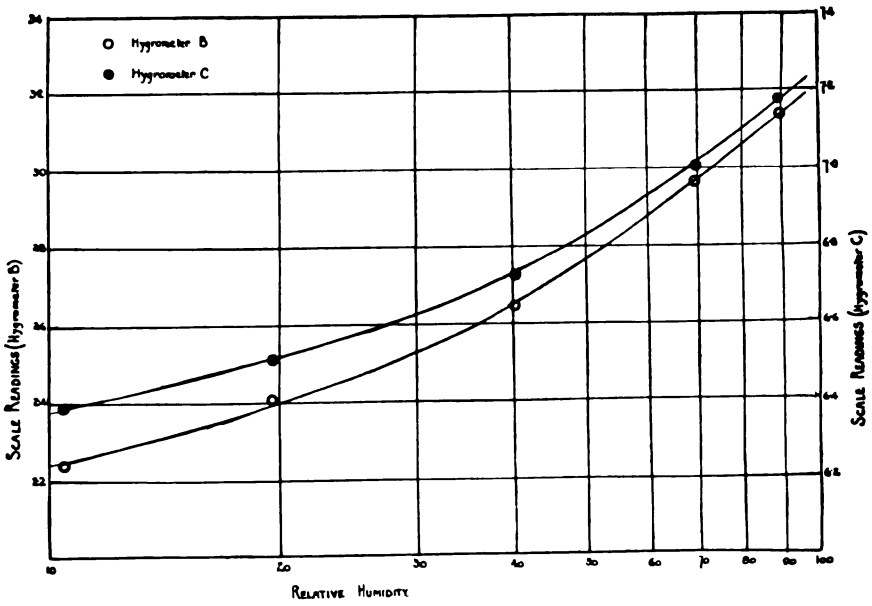

FIG. 4.—Relation between the logarithm of relative humidity and the length of hairs (Hygrometers B and C).

SECTION II.

Extension of Hair under a Constant Strain.

It was shown above that the hair shows a gradual extension under a constant load under conditions of changing humidity. To study this effect under constant humidity two hairs, 50 cm. and 76 cm. long, were suspended in burette tubes as in the instrument of Type C. Cork borer tubes weighing 9 grams and 12 grams respectively, were attached to these hairs. The burettes were closed and as the temperature of the room during the experiment did not vary more than a fraction of a degree, the hairs were at a constant humidity throughout.

The results plotted in Fig. 5 show that the rate of extension is constant for the first 10 days, and then changes to a smaller value which is maintained constant for the remainder of the experiment (3 months).

Experiments were performed to find the minimum weight necessary to produce this gradual extension; it was noticed that this varied with the individual hair, some hairs showing the effect with a 2 grm. weight while others showed no extension with 7 grm. weight. In this connection attention might be drawn to the fact shown very clearly in Fig. 5 that no two hairs behave under tension quantitatively the same. Thus a 50 cm. hair stretched by a 9 grm. weight extended approximately 4 mm. in 12 days as against the 2 mm. of a 76 cm. hair stretched by a 12 grm. weight.

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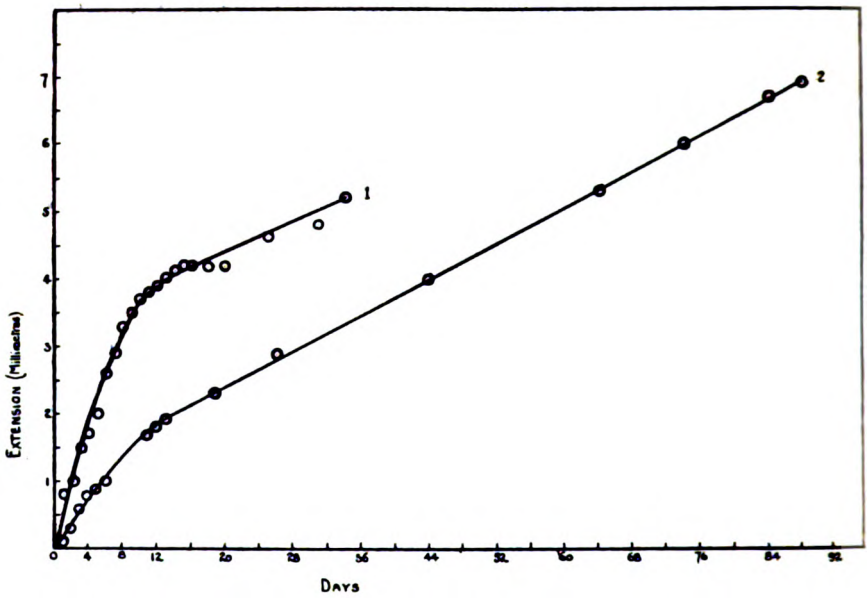

FIG. 5.—Extension of Hair under Constant Tension and Humidity.
(Curve 1, Length of Hair 50 cm., Attached Weight 9 gms. Curve 2, Length of Hair 76 cms., Attached Weight 12 gms.)

It might be noted that in hygrometers in actual use such extreme overloading is avoided, *e.g.*, in the Negretti and Zambra hygrometer the average tension of the hairs is 1/3 grm. With all such instruments, however, where friction in bearings and pivots is likely to affect the results, it may be desirable to calibrate them afresh after they have been used some time. This will be clear from a reference to Table IV. where most of the readings of the instrument are shown higher than the actual humidity and this in spite of the fact that the instrument was first calibrated by the makers. In this connection reference might again be made to Griffiths' remarks quoted in the preamble.

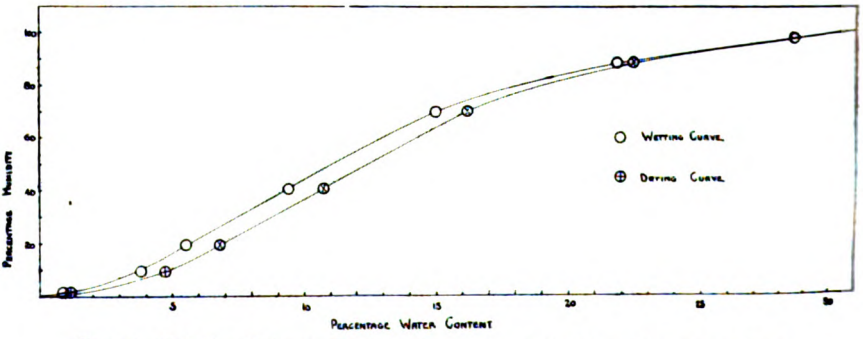

FIG. 6.—Relation Between Vapour Pressure and Moisture Content of Hair (Weight Hair Hygrometer).

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Section III.

Weight Hair Hygrometer.

A hair hygrometer in which the variations in weight, instead of length, are measured, could be used for humidity measurements, provided the equilibrium moisture contents corresponding to different vapour pressures follow a smooth relationship.

To study this point about 1 grm. of hair, cut into small pieces and cleaned by washing with benzene, was put in a squat weighing bottle with a ground in lid, and exposed to sulphuric acid-water mixtures of various humidities contained in a shallow crystallising dish in a vacuum desiccator. Equilibrium was attained in about 10-12 hours though the exposure was continued for 24 hours. Before opening the desiccator the air was let in through a small tube containing soda lime and cotton wool. It was found that 1 grm. of dry hair would take up little more than 0.3 grm. of moisture from a saturated atmosphere, but the equilibrium moisture content corresponding to a particular humidity is slightly less when the hair is taking up moisture than when it is losing it. This will be clear from Fig. 6, in which are plotted the moisture contents at various humidities, both for drying and wetting. It might be stated that this difference is not due to a slower rate of absorption of vapours as compared with drying, since longer exposure apparently does not make any difference, nor does it seem to be due to any fundamental change in the cell structure, as whatever the starting point (short of complete dryness) the equilibrium values fall on two distinct curves—the drying curve and the wetting curve. As was pointed out before, this hysteresis effect is in the reverse direction to that obtained when measurements are taken in terms of the extension of the hair.

In order to find the vapour pressure of a moist substance it was kept in a vacuum desiccator together with the hygrometer, which was weighed at the end of 24 hours, and the vapour pressure corresponding to the moisture content thus found read off from the drying or wetting curve, according to the direction from which equilibrium was approached.

In order to test the degree of accuracy of the weight hair hygrometer, the relative humidities of sulphuric acid-water mixtures were determined by this method and compared with those calculated from density measurements. The results are recorded in Table V., and show a close agreement between the two sets of values.

TABLE V.—Comparison of related humidities determined by a weight hair hygrometer and the density of a sulphuric acid-water mixture.

Sulphuric acid-water mixture.	Relative Humidity per cent.	
	Calculated from density.	Observed. (Hygrometer)
1	2.5	2.5
2	32.0	31.0
3	48.0	47.5
4	69.7	69.5

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Samples of soil were brought to definite humidities by prolonged exposure to sulphuric acid-water mixtures in vacuum desiccators. The relative humidities of these samples were measured by the hygrometer. These values are recorded in Table VI.

TABLE VI.—COMPARISON OF HUMIDITIES OF SAMPLES OF SOIL DETERMINED BY A WEIGHT HAIR HYGROMETER AND BY EXPOSURE TO VARIOUS SULPHURIC ACID-WATER MIXTURES.

Moisture Content. Per. cent.	Relative Humidity. Per cent.	Relative Humidity. Determined by Hygrometer. Per cent.
4.28	83	83
3.05	65	65
2.00	35	30
1.32	16	17
1.01	10	10

The results again show a satisfactory agreement between the actual values for humidities and those found by the hygrometer. The use of the weight hair hygrometer therefore can be recommended for determining vapour pressures of substances holding water. Large quantities of suitable sulphuric acid-water mixtures are made up giving a series of relative humidities ranging from 5 to 95 per cent. The actual values of these relative humidities are evaluated from the temperature and density of the acid concerned by means of the data given by Wilson.[3] In practice it is more convenient to use only the drying or the wetting curve for interpolating humidity values, the hygrometer after each determination being brought to 95 per cent. or 5 per cent. humidity respectively. The reproduction of this high or low point ensures that the calibration curve has not shifted through such causes as the accidental introduction of foreign bodies into the weighing bottle. Where a number of humidity determinations are to be made in a short time several hygrometers can be calibrated and used in different desiccators. Its use for finding the humidity of the atmosphere has not been tested; the long time required to attain a state of equilibrium would be a serious drawback against its use for this purpose.

SUMMARY.

(1) A study has been made of four types of hair hygrometers in which the total load on the hairs consists of a weight. These were taken through a series of humidity changes controlled by sulphuric acid-water mixtures. It is shown that, when the hair is loaded with a weight of two grams, or more, it undergoes a slow extension which extends over a period of several weeks. Hair under a smaller load shows no such effect and the readings at various humidities can be reproduced with sufficient accuracy to measure humidity within two per cent.

(2) Alterations in the length of the hair due to changes in humidity show a hysteresis effect which is apparently in the reverse direction to that when measurements are taken in terms of change in weight.

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(3) A simple form of weight hair hygrometer has been described, which can be used for measuring the vapour pressure of moist substances.

ACKNOWLEDGMENTS.

The work here described was carried out during the tenure of a Research Scholarship from the Punjab Drainage Board, to whom my thanks are due. I wish also to record my thanks to the members of the staff of the Soil Physics Department, for helpful criticism and useful suggestions.

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[1] Whipple, F. J. W., *London, Proc. Phys. Soc.*, **34**, 1922, p. 50.
[2] Griffiths, E., *London, Proc. Phys. Soc.*, **34**, 1922, p. 30.
[3] Wilson, R. E., *Calcutta, J. Ind. Eng. Chem.*, **13**, 1921, p. 326.

DISCUSSION.

Mr. L. H. G. DINES said that he had been working on hair hygrometers lately and there were several points which bore on the matters treated in the paper. First it seemed strange that while authors frequently mentioned the evil effects of excessive loading of hairs, no one ever mentioned that human hairs commonly used differed widely in cross-section among themselves. The only satisfactory way of stating permissive loads was to give them in load per cross-section. He had found that 60 kgs. per cm.^{2} was a safe load and that very little trouble was experienced from shifting zeros if this was not exceeded. Taking the average diameter of human hairs, this figure is of the same order as the safe load mentioned in the paper. Another practical point was that a hair could be seasoned and its initial tendency to stretch be got over quickly and finally if, when set up under its working load, it was immersed in water at 110°F. for half an hour. With reference to hysteresis, he had found that the contraction of the hair from its "wet" length was strongly determined by its recent history with respect to relative humidity. This fact had been noted by other workers long ago (*cf.* Ferguson in the *Blue Hill Meteorological Observations*, 1903-1904). Two extreme cases might be mentioned which the speaker had examined: (1) Hairs which had recently been wetted by immersion, (2) hairs which had been kept in air of relative humidity 20 per cent. for a day or two. Tests made under (1) showed nearly a straight line law between relative humidity and contraction, those under (2) the usual logarithmic law. The two curves when plotted differed by about ten per cent. on the humidity scale at a relative humidity of 60 per cent. and tended to approach each other within two or three per cent. at 25 per cent. Moreover, the scatter of the observations made in case (1) at about 20-30 per cent. was small, and this seemed to suggest a speedy way of calibrating any particular hair. The hair could first be immersed in water or exposed to 100 per cent. humidity (the effect is the same) and a reading taken. Next, one or two observations could quickly be made at about 25 per cent., and finally, by assuming that the shape and characteristics of the curves in cases (1) and (2) between 100 per cent. and 25 per cent. were the same for all hairs, draw them from the observational knowledge of the ends of curve (1) alone.

In reply to a remark by Sir NAPIER SHAW, Mr. DINES said that the temperature coefficient of hairs was a subject on which the opinions of different workers varied very greatly. He had found that at ordinary temperatures it was about the same as that of brass. He had made no experiments at low temperatures.

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The Rainfall of Ireland.

Mr. E. W. M. Murphy, F.R.Met.Soc., Hon. Secretary of the Irish Rainfall Association, has published a pamphlet[1] on the Rainfall of Ireland. It is a companion to the series which has been published annually since 1918, and is written primarily to stimulate interest among observers as "a brief summary . . . of Irish rainfall records . . . with a few notes on other meteorological subjects." It includes a table giving the mean annual rainfall for some 100 stations where records cover ten years or more. The extreme values illustrate the uniformity of the rainfall in Ireland. The annual fall has varied from 14 inches to 141 inches, compared with 10 inches to 240 inches in Great Britain. The largest monthly total on record is 25 inches, compared with over 50 inches recorded in both the English Lake District and in Snowdonia. The largest daily fall is 5.71 inches, while a measurement of over nine inches has been recorded on two occasions in Great Britain. It is to be regretted that the Howard gauge is described as "by no means a bad pattern for Ireland," since with its shallow funnel loss is likely to occur during snow, heavy rain or hail.

J. G.

[1] *The Rainfall of Ireland*, Irish Rainfall Association, Clonmel, November, 1926, 11 pp.

Evaporation at Stoner Hill, Petersfield, during 1926.

HEIGHT OF GAUGE ABOVE GROUND, 0 FT. 3 INS., ABOVE MEAN SEA-LEVEL 747 FT., SIDE OF GAUGE 4 FT., CAPACITY 250 GALLONS.

Month.	Amount.	Month.	Amount.
	ins.		ins.
January	0.14*	August	2.23
February	0.36	September	1.51
March	0.06	October	1.15
April	1.10	November	0.46
May	2.29	December	0.11
June	2.64		
July	2.43†	Total	15.38

* Tank frozen several days. Monthly value adopted after correspondence with the Meteorological Office.

† Tank drained eight days for painting. Monthly value from figures supplied by the Meteorological Office.

In forwarding the above figures, Mr. C. J. P. Cave writes:—

The evaporation tank, the property of the Royal Meteorological Society, has been maintained at Stoner Hill, Petersfield, during the past year. Some difficulties in readings were experienced in January, owing to the freezing of the water. But the most serious break in the readings occurred in July, when the tank was cleaned out. It was then found that there were several rust spots on the tank, and it was feared that these might develop into holes unless they were attended to promptly. The tank was accordingly repainted inside, but, owing to the state of the weather, this could not be finished quickly, and the tank was empty for eight days.

C. J. P. CAVE.

January 6, 1927.

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THE VARIABILITY OF AVERAGE MONTHLY RAINFALL THROUGHOUT THE YEAR.

By JOHN GLASSPOOLE, M.Sc., Ph.D.

[Manuscript received December 6, 1926—Read February 16, 1927.]

§1. Introduction.

In a paper read before the Institution of Water Engineers in December 1925, Capt. W. N. McClean[1] drew attention to the relatively high seasonal variation in the rainfall at stations in the western Highlands of Scotland. He pointed out that the variability was greatest at the wettest stations. As the investigation was confined to Scotland no information was given as to whether a similar relationship held elsewhere in the British Isles. The seasonal variability of the rainfall over the whole of the British Isles was, however, dealt with in an earlier paper published by the Royal Meteorological Society in 1916,[2] when it was shown that the variability was much larger in the western Highlands of Scotland than elsewhere in these islands. The following comment on the paper by Dr. H. R. Mill was, however, reported: "It is precisely in this anomalous region" (N.W. Scotland) "that the data are least satisfactory and he was not sure whether the lines represented a physical fact or whether they were founded on insufficient data." The average used in that paper was the 35 years 1875 to 1909. The Meteorological Office has recently published a new set of averages, covering the years 1881 to 1915.[3] The stations with computed averages being now more numerous and more evenly distributed, a re-investigation of the seasonal variability over the British Isles has been undertaken.

The variability of the monthly averages at any station has been considered from two aspects. In the first place the variability has been measured by the difference between the largest and the smallest monthly average. Thus, at Greenwich Observatory the wettest month is October, with an average of 2.53 ins., and the driest month April, with 1.47 ins., so that the difference in the monthly averages is 1.06 ins. This method of dealing with the variability has the disadvantage of taking into account only the two extreme months. The second method considers the mean deviation of the monthly totals from the mean monthly fall.

§2. The Range of the Monthly Averages.

The difference between the largest and the smallest monthly average for some 350 stations distributed over the British Isles is set out in Table I. (pp. 137-142). The difference is nowhere

[1] "An analysis of Scottish Rainfall Records," *Trans. Inst. Water Engineers*, **30**, 1925.

[2] Comissopulos, N. A., "On the Seasonal Variability of Rainfall over the British Isles," *Q.J.R. Meteor. Soc.*, Vol. **42** (1916).

[3] *Book of Normals, Section V.*, Meteorological Office, London.

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less than an inch. In the table below are given the stations with the smallest differences together with the corresponding average annual rainfall.

County.	Station.	Difference.	Average Annual Rainfall.
		ins.	ins.
Essex - - - -	Bradwell-on-Sea - - -	1.00	20.68
Inverness - -	Inverness - - - - -	1.01	26.87
Northants - -	Wellingborough - - -	1.03	24.27
Worcester - -	Lincombe Lock - - -	1.03	25.57
Warwick - -	Stratford-on-Avon - -	1.03	23.91
Gloucester - -	Cheltenham - - - -	1.04	26.47

These small differences occur at stations with a small average annual rainfall. The largest values occur at stations in the usually wet areas of the British Isles and in the table below the largest values in Table I. are set out together with the average annual rainfall as in the case of the stations with the smallest variations.

County.	Station.	Difference.	Average Annual Rainfall.
		ins.	ins.
Cumberland - -	Seathwaite - - - -	9.82	129.48
Inverness - -	Glenquoich - - - -	9.75	110.75
Inverness - -	Glenfinnan - - - -	8.71	107.98
Westmorland -	Patterdale Hill - - -	7.34	86.40
Inverness - -	Fort William - - - -	6.57	78.80
Lancashire - -	Monk Coniston - - -	6.50	83.85
Merioneth - -	Blaenau Festiniog - -	6.35	97.14
Ross - - - -	Glencarron Lodge - -	5.32	87.75

The values given in Table I. for the difference between the largest and smallest monthly averages have been plotted and the distribution is shown in Fig. 1. The map indicates that the area of most uniform monthly rainfall is central and eastern England. In this region, as well as along the east coast of northern England and of Scotland (including the valleys of the Rivers Spey and Dee) and along the east coast of Ireland stretching inland to Co. Cavan, the difference is less than 1.5 ins. The value increases to the north-west, *i.e.*, in the mountainous regions. It exceeds three inches over the greater part of the Devon-Cornwall peninsula, practically the whole of Wales, the English Lake District and part of the Pennines; and over nearly half the area of Scotland, including the southern uplands and the western Highlands and over large areas in Ireland in Connemara and the mountains of Cork and Kerry. The value exceeds six inches only in Snowdonia, the English Lake District and the western Highlands of Scotland. The latter area is extensive. Nine inches is only exceeded at stations in the English Lake District and round Loch Quoich in the western Highlands.

That the largest differences occur at very wet stations is to be expected. It has been shown previously[4] that while in mountainous

[4] See for example *British Rainfall*, 1914, p. 43.

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areas there may be considerable diversity from place to place in the annual rainfall, the variation in the proportion of the year's rain falling in the different months is only slight. Thus for the two stations in the western Highlands of Scotland, Glenquoich, on Loch Quoich, and Fort Augustus situated 25 miles to the north-east, but in the same mountain range, the following isomeric[5] values have been computed from the averages given in the *Book of Normals*.

FIG. 1.

The isomeric values at the two stations are shown to be similar, December being wetter than June by 8.8 per cent. and 8.6 per cent. of the respective annual averages. Glenquoich is, however, nearly three times as wet as Fort Augustus, the average annual rainfall at the two stations being 110.75 ins. and 44.20 ins. respectively. Thus the difference between the values of 9.75 ins.

[5] The percentage which the average monthly rainfall forms of the annual average is termed an " isomeric " value.

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and 3.78 ins., which are the differences between the largest and smallest monthly averages at the two stations, is proportional to the difference between the average annual totals. Similarly, elsewhere in the British Isles the wettest stations give the largest differences, and average annual rainfall is the best indication of the range in the monthly averages.

TABLE II.—Average Monthly Rainfall as Percentages of the Average Annual Total.

Month.	Jan.	Feb.	Mar.	April.	May.	June.	July.
Glenquoich	12.4	9.4	8.8	5.9	4.9	4.4	5.8
Fort Augustus ...	12.2	9.5	8.2	5.8	5.4	4.6	6.3

Month.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Glenquoich	7.4	7.8	9.0	11.0	13.2	100.0
Fort Augustus	7.8	7.7	8.9	10.4	13.2	100.0

§3. Mean Deviation of the Monthly Averages at Individual Stations.

The measure of the variability in the second method is taken to be the mean deviation of the monthly averages from the mean monthly fall. One difficulty is that the months are of unequal length so that even if the same amount of rain fell on each day of the year, the mean deviation would differ from zero by some finite quantity. Instead, therefore, of using the actual monthly averages, the mean daily fall has been utilised. This practice was suggested by Col. E. Gold in the discussion on the paper by Mr. Comissopulos to which reference has already been made. The mean of these twelve averages was thus determined and the monthly values expressed as percentage departures from that mean. For each station, values are given in columns 4 and 5 of Table I. for (*a*) the mean of the twelve mean daily falls for each month, and (*b*) the mean deviations from the mean daily rainfall for the twelve months, expressed as a percentage of the value in (*a*) above. The method of arriving at the results is illustrated below in the case of the record at Greenwich Observatory :—

	Jan.	Feb.	Mar.	April.	May.	June.	July.
Average in ins.	1.69	1.57	1.73	1.47	1.73	2.02	2.24
Mean rain per day in ins.	.0545	.0557	.0558	.0490	.0558	.0671	.0723
% departure from mean...	−15	−13	−13	−24	−13	+ 4	+13

	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average in ins.	2.19	1.79	2.53	2.28	2.26	23.50
Mean rain per day in ins. ...	.0706	.0597	.0816	.0760	.0729	...
% departure from mean ...	+10	− 7	+27	+18	+13	...

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The mean of the mean rainfalls per day for the twelve months is .0643, the sum of the percentage departures irrespective of sign is 170, and the mean deviation, obtained by dividing by 12, is 14.2.

Some of the smallest and largest values given in Table I. for the mean deviation are set out below :—

County.	Station.	Mean Deviation.	Average Annual Rainfall.
		per cent.	in.
Cambridge	Cherryhinton	10.2	21.61
Huntingdon	Waresley Park	10.8	23.99
Armagh	Armagh	11.3	31.75
Sutherland	Dunrobin Castle	11.5	31.65
Moray	Grantown-on-Spey	11.7	31.15
Cambridge	Stretham Engine	11.8	21.20
Inverness	Inverness	11.8	26.87
Devon	Holne Vicarage	29.2	59.80
Inverness	Glenquoich	27.7	110.75
Brecon	Nanthir Reservoir	27.2	59.57
Westmorland	Patterdale Hall	26.3	86.40
Cornwall	Altarnon Vicarage	26.0	59.17
Inverness	Fort William	25.7	78.80
Devon	Okehampton	25.7	46.56
Inverness	Fort Augustus	25.5	44.20

The mean deviation is less than 15 per cent. over a large portion of central England, over central and north-eastern Ireland and along the east coast of Scotland from Montrose to Wick. In England the area is essentially an inland region and is suggestive of that which would be obtained by a line drawn at a distance of about fifty miles from the coast. The area in Ireland is also mainly inland but includes a good deal of coast opposite to the south-west of Scotland and the Isle of Man. The area in Scotland occurs entirely along the east coast and up the east coast valleys. In each country the mean deviation exceeds 20 per cent. in the west, but in Scotland the area is most widespread in the north-west. The deviation is more than 20 per cent. over the Devon-Cornwall peninsula, the greater part of Wales and the English Lake District, as well as along a well-marked strip of the south coast. In Ireland there are two well-marked areas in the south-west of Munster and the west of Connaught. The areas in Scotland are much more extensive, occurring in the southern uplands and over practically the whole of the north-west, stretching from Campbeltown in the south to Cape Wrath in the north, and inland as far as Dalnaspidal and Crieff. The mean deviation exceeds 25 per cent. in four well-marked areas, viz., in the Devon-Cornwall peninsula, South Wales, the English Lake District and over a large area in the neighbourhood of the Caledonian Canal.

It is of interest to consider the values on which the mean deviation is based at individual stations. For selected stations in the British Isles the percentage departures from the mean monthly rainfall are shown in Fig. 3. The stations in the first group lie practically in a straight line from Land's End to Cromer, *i.e.*, in a direction from SW to NE across the British Isles. The second group includes stations arranged in a line from the north-west of Ireland to the Moray Firth. In the diagram the values for January

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are repeated on the right-hand side to complete the curves. The vertical scale values are indicated by the extremes which are given in each case. Maps of the British Isles showing the month with the highest or lowest average monthly rainfall are given in *British Rainfall* 1920, p. 265. In the west the wettest month of the year is December, and further east, October. At Nairn the wettest month is August. The month with the least rainfall is usually

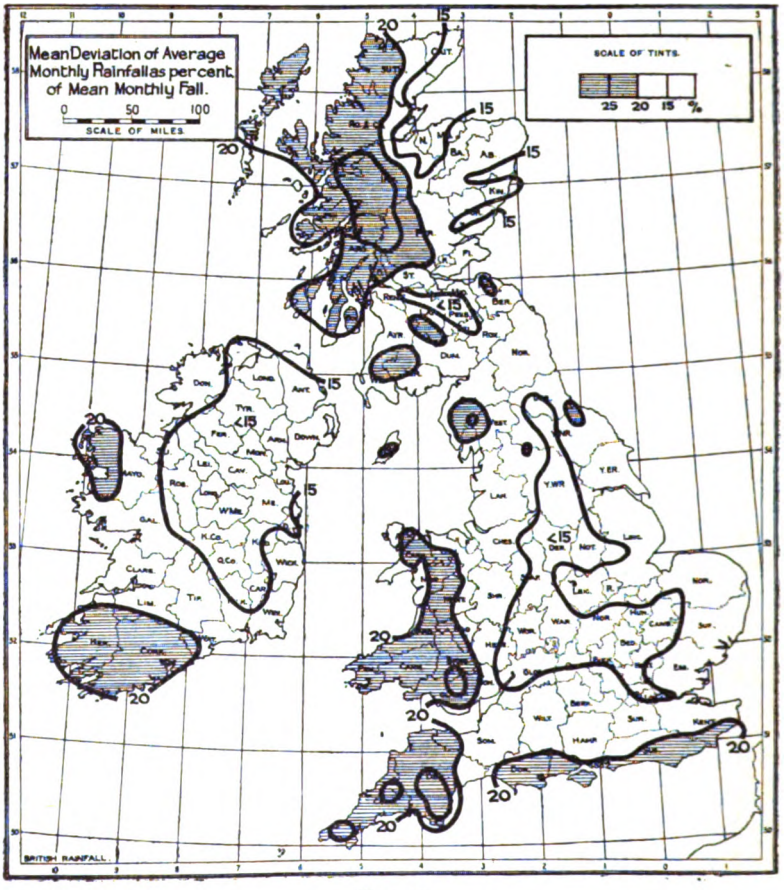
Mean Deviation of Average Monthly Rainfall as per cent. of Mean Monthly Fall.
0 50 100
SCALE OF MILES
SCALE OF TINTS.
25 20 15 %
BRITISH RAINFALL

FIG. 2.

six or seven months earlier, generally April. It is May in the south-west of England, north-west of Ireland and parts of the west of Scotland; March in central England and June in the north of Scotland. The secondary minimum in September is well marked at all stations except Nairn, while there is generally a secondary maximum in August or July. The variation over the country is illustrated by the diagram Fig. 3. As previously explained, the values are based on the mean rain per day and are independent of the varying length of the months.

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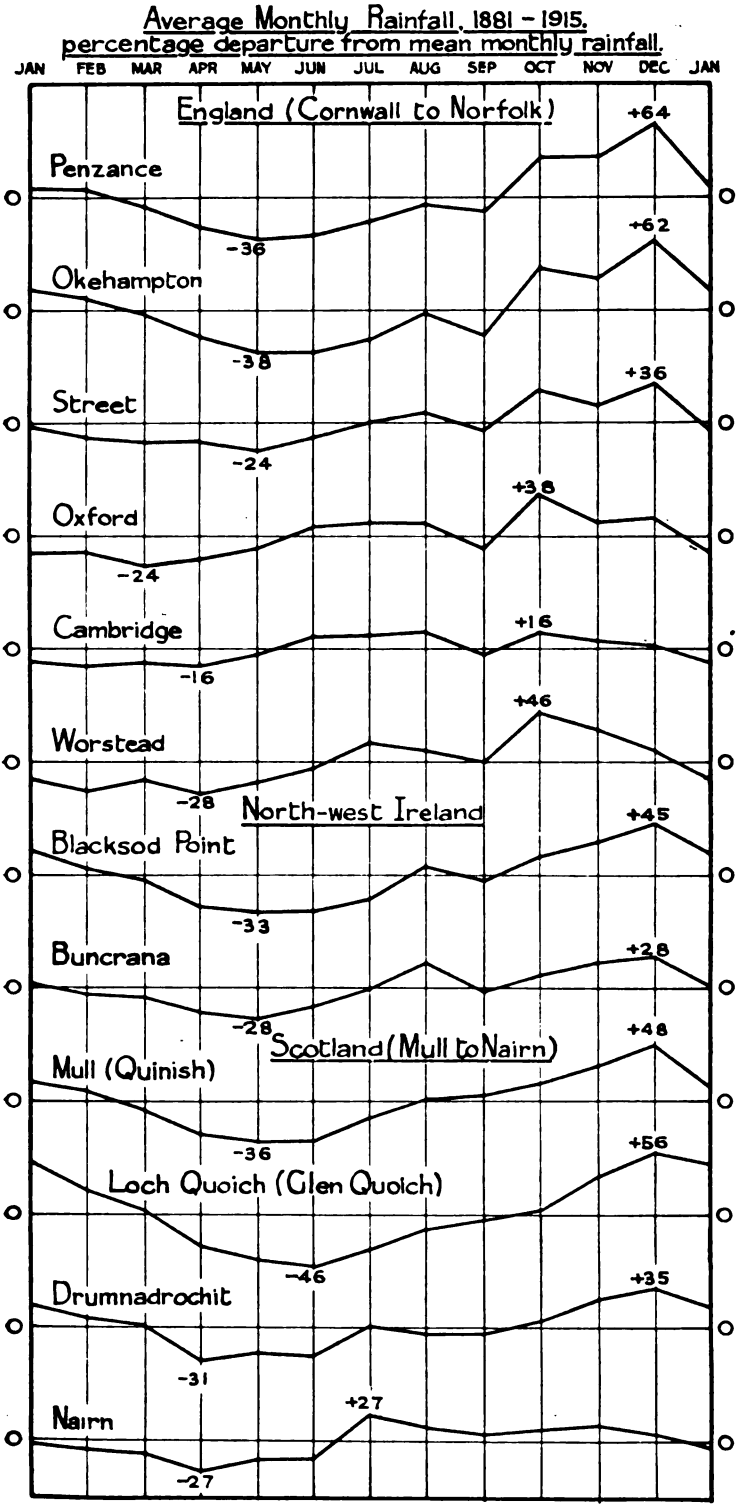

Fig. 3.

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§4. The relation of the variability of average monthly rainfall to the mean rainfall per day.

The stations have been classified according to the mean rainfall per day and the corresponding values for the variability given in Table I. also noted. The mean of the values for each group is given in the table below (Table III.).

TABLE III.—Classification of the values given in Table I. according to the mean rainfall per day.

Mean rainfall per day (ins.)	Less than .0639	.0640 to .0699	.0700 to .0799	.0800 to .0899	.0900 to .0999	.1000 to .1199	.1200 to .1699	Greater than .1700
Equivalent average annual rainfall (ins.)	Less than 23	23 to 26	26 to 29	29 to 33	33 to 36	36 to 44	44 to 62	Greater than 62
No. of Stations	19	40	55	61	45	56	55	19
Group Means. Mean rainfall per day (ins.)	.0608	.0675	.0749	.0851	.0939	.1091	.1407	.2201
Group Means. Equivalent average annual rainfall (ins.)	22	25	27	31	34	40	51	83
Group Means. Mean deviation (per cent.)	16.0	15.8	16.3	16.0	17.3	17.5	20.5	22.9
Group Means. Range (ins.)	1.25	1.32	1.53	1.70	1.98	2.28	3.41	6.27

It is apparent that while the range increases steadily with the annual rainfall, the percentage mean deviation only increases in the last four columns. For groups of stations with a mean annual rainfall of 22, 25, 27 and 31 inches respectively, the value of the percentage mean deviation is about 16 per cent. in each case. The 55 stations in Table I. with an annual rainfall between 44 and 62 inches give a mean value of 20 per cent., and the 19 wettest stations in Table I. a mean value of 23 per cent. for the mean deviation.

The steady increase in the range with the annual rainfall, shown in Table III., is illustrated in Fig. 4, where the values of the range (R) for each group are plotted against the mean rainfall per day (M), the equivalent values for the average annual rainfall being indicated below. The line joining these points is approximately given by the equation $R = -.144 + 18.7\,M + 40.9\,M^2$, and the line represented by this equation is shown on the diagram Fig. 4, which has been extended beyond the values given in Table III. The values for the individual stations given in Table I. are indicated in Fig. 4 by dots, while the values for each group set out in Table III. are shown by crosses. For all practical purposes M can be taken as the average annual rainfall divided by 365.

§5. Variability of average monthly rainfall at some long period stations compared with that for the 35 years 1881 to 1915.

So far, the average rainfall has been considered only for the 35 years 1881 to 1915, and it is of interest to know whether the variability of average monthly rainfall is similar for longer periods.

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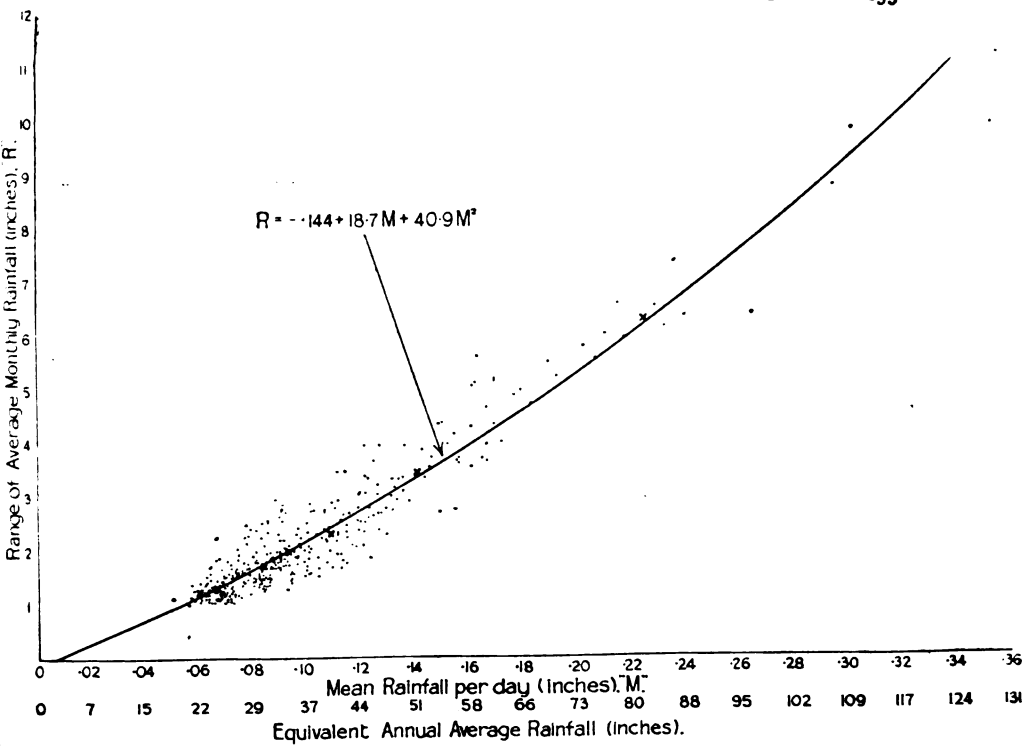
R = ·144 + 18·7M + 40·9M²
Range of Average Monthly Rainfall (inches), R.
Mean Rainfall per day (Inches), M.
Equivalent Annual Average Rainfall (Inches).

Fig. 4.

For four stations details are given for the longest period of available data alongside similar information extracted from Table I. Two stations, viz., Greenwich and Spalding, are situated in the dry area of the east of England, while the remaining two, viz., Seathwaite and Glenquoich, are wet stations in the west of Great Britain. The difference in the rainfall is indicated by the mean rainfall per day at the two pairs of stations:—

TABLE IV.—COMPARISON OF THE VARIABILITY OF AVERAGE MONTHLY RAINFALL FOR LONG PERIODS WITH THAT FOR 35 YEARS 1881 TO 1915.

Station and County.	Greenwich, London.		Spalding, Lincoln.		Seathwaite, Cumberland.		Glenquoich, Inverness.	
Period.	1881–1915.	1815–1921.	1881–1915.	1829–1921.	1881–1915.	1845–1921.	1881–1915.	1868–1924.
No. of Years.	35	107	35	93	35	77	35	57
Difference between greatest and least average monthly rainfall (ins.)	1.06	1.07	1.09	1.10	9.82	9.02	9.75	8.46
Mean rainfall per day (ins.)	.0643	.066	.0643	.0670	.3546	.3619	.3034	.3136
Mean deviation of monthly rainfall (per cent.)	14.2	13.3	16.0	14.5	22.0	22.7	27.7	22.8

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At the two dry stations the mean rainfall per day is about 3 per cent. less in the case of the 35 years, the range of the monthly rainfall in inches is a trifle less, while the mean deviation is about 8 per cent. more. The effect of the longer period is therefore to smooth out the irregularities in the monthly rainfall. At the two wet stations the mean rainfall per day is again less in the case of the 35 years by about the same amount, the range of the monthly rainfall in inches is appreciably more, while the mean deviation is a trifle less in the case of Seathwaite and considerably more in the case of Glenquoich. Details of the changes in the largest and smallest monthly averages for the two periods are indicated below (Table V.).

TABLE V.—COMPARISON OF EXTREME MONTHLY AVERAGES FOR THE 35 YEARS 1881 TO 1915 AND FOR LONG PERIODS.

	Seathwaite.				Glenquoich.			
	Largest average.		Smallest Average.		Largest Average.		Smallest Average.	
	1881–1915.	1845–1921.	1881–1915.	1845–1921.	1881–1915.	1868–1924.	1881–1915.	1868–1924.
Amount (ins.) .	16.34	15.88	6.52	6.86	14.66	13.92	4.91	5.46
Month . . .	Dec.	Dec.	June.	May.	Dec.	Dec.	June.	June.

So that again the effect of the longer period is to give more uniform monthly averages. This is particularly the case at Glenquoich, where the fall of the spring months is not so much smaller than that of the other months in the case of the longer period.

It is important, therefore, to specify that the diagrams Figs. 1 and 2 are for the 35 years 1881 to 1915, and it appears that, if it had been possible to construct such maps for a longer period, the variability shown thereon would have been somewhat smaller.

Acknowledgment is due to Mr. M. J. Salter, of Mickleton, for the preparation of Table I. of this paper.

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.

County.	Station.‡	Difference. Maximum-Minimum.	Mean Rainfall per Day*	Mean Deviation of Monthly Rainfall.†
ENGLAND.		ins.	ins.	%
London	Greenwich Obsy.	1.06	.0643	14.2
,,	Camden Square	1.09	.0669	13.5
Surrey	Dorking	1.88	.0882	16.5
,,	Kew Observatory	1.25	.0651	15.2
,,	Haslemere	2.39	.0975	19.2
Kent	Tenterden	1.92	.0752	19.5
,,	Dungeness	2.22	.0666	24.2
,,	Folkestone	2.37	.0795	21.7
,,	Broadstairs	1.71	.0649	17.8
,,	Margate	1.57	.0622	17.8
,,	Selling	1.81	.0822	16.3
,,	Edenbridge	1.74	.0840	17.8
,,	Sevenoaks	1.51	.0742	15.0
,,	Rochester	1.39	.0712	15.5
Sussex	Chichester	2.12	.0786	20.0
,,	Patching Farm	2.21	.0842	20.2
,,	Horsham	1.98	.0820	19.0
,,	Brighton	2.34	.0819	22.0
,,	Eastbourne	2.49	.0841	22.2
,,	St. Leonards	2.22	.0776	20.2
,,	Hailsham Vic.	2.49	.0864	22.5
,,	Crowborough	2.42	.0985	20.0
Hants	Ventnor	2.25	.0790	23.5
,,	Totland Bay	2.45	.0779	22.8
,,	Bournemouth	2.51	.0862	22.8
,,	Fordingbridge	2.32	.0866	23.3
,,	Southampton	2.09	.0846	19.3
,,	West Dean	1.88	.0803	18.3
,,	Ovington Rectory	2.16	.0908	18.2
,,	Sherborne St. John	1.75	.0792	16.2
Berks	Wellington College	1.67	.0723	15.7
,,	Newbury	1.68	.0794	16.2
Middlesex	Enfield	1.25	.0677	15.3
Herts	Hemel Hempstead	1.62	.0762	14.5
,,	Bennington House	1.19	.0682	15.3
Bucks	High Wycombe	1.56	.0708	16.3
,,	Newport Pagnall	1.24	.0647	15.3
Oxford	Middleton Park	1.45	.0731	14.5
,,	Magdalen College	1.26	.0651	16.5
Northants	Wellingborough	1.03	.0664	12.8
,,	Oundle	1.07	.0610	14.8
Hunts	Waresley Park	1.31	.0655	10.8
,,	Whittlesea Mare	1.25	.0584	18.3
Cambridge	Cherryhinton	1.08	.0590	10.2
,,	Stretham Engine	1.35	.0579	11.8
,,	Wisbech	1.34	.0628	16.3
Essex	Elsenham	1.19	.0673	14.7
,,	Shoeburyness	1.10	.0516	17.8
,,	Southend W.W.	1.22	.0578	16.5
,,	Bradwell-on-Sea	1.00	.0566	15.8
,,	Chelmsford	1.18	.0615	16.8
,,	Earls Colne	1.17	.0633	15.7
Suffolk	Hawkedon	1.18	.0682	15.2
,,	Ipswich	1.20	.0679	15.7

‡ The full names of the stations with the latitude and longitude of each station are given in the *Book of Normals, Section V., Meteorological Office, London.*

* This is actually the mean of the 12-monthly mean rainfalls per day and may therefore differ slightly from the value obtained by dividing the annual rainfall by the number of days in a year.

† The mean deviation of the monthly mean rainfalls per day for the 12 months in the year, is expressed as a percentage of the value in the previous column.*

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Suffolk	Rendlesham Hall	1.20	.0632	15.3
,,	Bury St. Edmunds	1.21	.0687	15.8
,,	Walsham-le-Willows	1.23	.0691	15.2
,,	Geldeston	1.45	.0647	16.5
Norfolk	Norwich	1.48	.0724	15.8
,,	Bylaugh Park	1.57	.0766	16.3
,,	Dilham	1.74	.0718	18.2
,,	L. Massingham	1.43	.0766	15.5
,,	Blakeney	1.34	.0630	16.3
,,	Swaffham	1.31	.0699	16.5
Wilts	Warminster	2.19	.1009	17.2
,,	Bishops Cannings	1.37	.0829	15.3
,,	Mildenhall	1.51	.0830	15.2
Dorset	Weymouth	2.03	.0766	23.0
,,	Bere Regis	2.68	.0922	24.2
,,	Beaminster	2.72	.1029	21.8
,,	Gillingham	1.97	.0897	17.8
Devon	Holne Vicarage	5.60	.1637	29.2
,,	Torquay	2.58	.0904	24.8
,,	Collumpton	2.27	.0965	19.5
,,	Sidmouth	1.83	.0886	17.2
,,	Lyme Regis	2.19	.0916	19.0
,,	Barnstaple	2.48	.1002	21.5
,,	Arlington Court	3.72	.1471	22.3
,,	Okehampton	3.96	.1274	25.7
,,	Torrington	2.68	.1074	22.2
Cornwall	Redruth	3.95	.1238	24.8
,,	Newquay	2.70	.0909	23.0
,,	Bude	2.52	.0916	22.3
,,	Penzance	3.47	.1120	24.8
,,	St. Austell	3.67	.1255	23.5
,,	Liskeard	3.47	.1166	23.7
,,	Empacombe	2.86	.1007	19.7
,,	Altarnon Vic.	5.05	.1619	26.0
Scilly	Tresco Abbey	2.92	.0893	24.0
Somerset	Chewton Mendip	2.62	.1231	17.2
,,	Street	1.49	.0806	15.2
,,	Milverton	2.32	.1003	19.5
,,	Cothelstone	1.98	.0956	17.8
Gloster	Quedgeley Ho.	1.13	.0763	14.0
,,	Cheltenham	1.04	.0724	13.7
,,	Clifton	1.72	.0947	16.5
,,	Fairford	1.15	.0701	15.8
,,	Sherborne Ho.	1.47	.0838	15.0
Hereford	Ross	1.40	.0772	13.3
,,	Kington	1.78	.0898	17.2
Shropshire	Bishops Castle	1.66	.0848	16.2
,,	Preen Manor	1.55	.0795	16.3
,,	Shifnal	1.21	.0715	14.7
Stafford	Market Drayton	1.57	.0789	16.2
,,	Rodbaston	1.20	.0760	14.7
,,	Tean	1.48	.0870	15.0
Worcester	Lincombe Lock	1.03	.0699	13.8
Warwick	Stratford-on-Avon	1.03	.0654	14.3
,,	Rugby School	1.22	.0699	14.8
,,	Coventry	1.09	.0711	13.3
,,	Farnborough	1.20	.0798	12.3
,,	Birmingham	1.09	.0724	14.0
Leicester	Kibworth Beauchamp	1.15	.0701	16.5

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Leicester	Thornton Res.	1.14	.0716	15.2
,,	Belvoir Castle	1.17	.0686	14.7
Rutland	Market Overton	1.33	.0733	15.0
Lincoln	Spalding	1.09	.0643	16.0
,,	Boston	1.39	.0624	16.3
,,	Rauceby Hall	1.19	.0692	14.3
,,	Skellingthorpe Hall	1.17	.0632	15.8
,,	Skegness	1.40	.0637	16.3
,,	Louth	1.57	.0765	15.0
,,	Market Rasen	1.39	.0697	17.2
,,	Brigg	1.42	.0694	16.8
Nottingham	Strelley Hall	1.17	.0698	14.3
,,	Hodsock Priory	1.16	.0645	14.5
Derby	Mickleover	1.07	.0712	15.2
,,	Belper	1.33	.0812	13.7
,,	Hardwick Hall	1.49	.0862	13.0
Cheshire	Runcorn	1.87	.0854	17.0
,,	Altrincham	1.71	.0917	15.7
,,	Woodhead Res.	2.24	.1303	15.0
,,	Buglawton Vic.	1.58	.0833	14.3
,,	Bidston Observatory	1.64	.0763	17.3
,,	Neston	1.58	.0747	18.2
Lancashire	Bury (Gin Hall)	2.35	.1194	15.7
,,	Burnley (Swinden)	2.08	.1212	15.3
,,	Stonyhurst College	2.35	.1273	15.3
,,	Wigan W.W.	1.87	.0967	16.3
,,	Southport	1.69	.0875	18.0
,,	Holker Hall	2.32	.1217	17.2
,,	Monk Coniston	6.50	.2296	22.8
,,	Blackpool	1.84	.0914	18.0
,,	Grizedale Res.	2.51	.1192	17.3
Yorks, W.R.	Sedbergh	2.06	.1493	16.0
,,	Sheffield	1.53	.0832	13.0
,,	Goole	1.24	.0626	17.5
,,	Huddersfield	1.70	.0929	14.0
,,	Garforth	1.24	.0677	14.8
,,	Bradford	1.47	.0858	14.0
,,	Malham Tarn	2.74	.1573	16.0
,,	York Museum	1.18	.0664	15.5
,,	Skipton	1.68	.0899	16.3
,,	Arncliffe Vic.	3.65	.1670	20.8
,,	Wetherby	1.27	.0724	13.8
,,	Harrogate	1.43	.0836	13.2
,,	Pateley Bridge	1.98	.1093	18.3
,,	Ripon	1.45	.0827	13.2
Yorks, E.R.	Patrington	1.51	.0637	19.5
,,	Hull	1.42	.0694	16.8
,,	Market Weighton	1.53	.0764	15.5
,,	Lowthorpe	1.58	.0723	17.0
Yorks, N.R.	Leyburn	1.74	.0893	17.0
,,	Felixkirk	1.21	.0725	16.0
,,	Rounton Grange	1.48	.0699	17.8
,,	Scarborough	1.54	.0714	16.3
,,	Whitby	1.41	.0676	16.3
,,	Lockwood Res.	2.26	.0903	19.7
,,	Middlesbrough	1.70	.0646	20.7
,,	Mickleton	1.63	.0906	15.3
Durham	Darlington	1.23	.0687	13.5
,,	Barnard Castle	1.40	.0813	12.5

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Durham	Wolsingham	1.77	.0909	14.2
,,	Durham Observatory	1.83	.0672	18.8
,,	Sunderland	1.53	.0699	17.0
Northumberland	Newcastle	1.61	.0743	15.5
,,	Hallington	1.58	.0772	16.5
,,	Cockle Park	1.76	.0784	16.5
,,	Rothbury	2.02	.0923	15.0
,,	Biddleston Hall	1.97	.0930	15.8
,,	Howick Hall	1.79	.0771	16.5
,,	Lilburn Tower	1.60	.0764	14.8
,,	Coldstream	1.78	.0817	17.2
Cumberland	Aspatria	2.30	.1120	16.8
,,	Carlisle	2.16	.0920	16.2
,,	Seathwaite	9.82	.3546	22.0
,,	Whitehaven	2.21	.1156	17.8
Westmorland	Kirkby Stephen	2.69	.1159	19.3
,,	Patterdale Hall	7.34	.2367	26.3
,,	Appleby	2.01	.0959	16.7
WALES.				
Monmouth	Llanfrechfa Grange	2.63	.1160	19.2
Glamorgan	Ystalyfera	4.87	.1773	21.7
Carmarthen	Carmarthen	3.00	.1321	21.0
,,	Llanwrda	3.71	.1574	20.2
Pembroke	Castle Malgwyn	3.02	.1198	23.7
,,	Stackpole Court	2.69	.1073	23.3
,,	Haverfordwest	3.20	.1268	23.0
Cardigan	Aberystwyth	2.67	.1271	19.0
Brecon	Nanthir Res.	5.12	.1630	27.2
,,	Brecon	4.29	.1615	24.0
Radnor	Nantgwilt	5.14	.1700	24.2
Montgomery	Newtown	1.93	.0957	17.5
,,	Lake Vyrnwy	3.97	.1525	21.8
Flint	Bodfari	1.81	.0750	18.7
Denbigh	Packsaddle Res.	1.84	.0875	16.3
Merioneth	Blaenau Festiniog	6.35	.2656	18.8
,,	Dolgelly	3.54	.1608	19.2
Carnarvon	Llandudno	1.78	.0821	18.0
,,	Glynllivon	3.03	.1225	21.5
Anglesley	Llwydiarth Esgob	2.28	.1041	20.3
Isle of Man	Douglas Cemetery	2.52	.1127	19.8
,,	Clypse Onchan	2.50	.1201	20.0
Jersey	St. Aubins	2.73	.0916	26.3
Guernsey	St. Peter Port	2.80	.0008	27.2
SCOTLAND.				
Wigtown	Corsewall	2.01	.0933	16.0
,,	Ardwell House	2.00	.0994	17.5
,,	Garliestown	2.36	.1069	18.5
Kirkcudbright	Dalry	4.32	.1193	24.0
,,	Auchencairn	2.77	.1287	17.5
,,	Cargen	2.74	.1226	18.8
Dumfries	Drumlanrig	2.79	.1192	19.5
,,	Moffat	3.89	.1434	23.2
,,	Byreburnfoot	2.44	.1150	17.3
Roxburgh	Branxholme	1.92	.0912	15.0
,,	Kelso	1.38	.0711	16.3
Selkirk	Selkirk	1.38	.0952	14.2
Peebles	North Esk Res.	1.73	.1080	13.5
Berwick	Marchmont Ho.	1.80	.0879	15.0
,,	West Foulden	1.51	.0696	16.2

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Haddington	Prestonkirk	1.84	.0679	20.5
Midlothian	Gladhouse Res.	1.72	.0960	14.0
,,	West Calder	1.88	.0976	14.5
,,	Edinburgh Univ.	1.80	.0711	17.7
Lanark	Cambus Wallace	1.65	.0849	15.2
,,	Glasgow Obsy	2.07	.1017	14.5
,,	Hillend Res.	1.97	.1021	15.3
Ayr	North Craig Res.	2.46	.1128	19.2
,,	Dalmellington	2.73	.1318	18.0
,,	Girvan (Pinmore)	3.10	.1364	19.7
Renfrew	Loch Thom	3.99	.1790	18.8
Stirling	Falkirk	1.94	.0871	16.8
,,	Buchlyvie	2.90	.1377	18.7
Argyll	Glenborrodale	5.49	.1889	22.8
,,	Poltalloch	3.35	.1443	19.5
,,	Campbeltown	3.01	.1234	19.7
,,	Skipness Castle	2.92	.1335	20.8
,,	Inveraray Castle	6.00	.2115	22.0
,,	Islay (Eallabus)	3.31	.1338	20.8
,,	Lismore	3.04	.1196	18.2
,,	Mull (Quinish)	4.16	.1554	20.8
Kinross	Loch Leven Sluice	2.02	.0978	16.3
Fife	Collinsburgh	1.69	.0881	17.0
Perth	Loch Dhu	5.91	.2185	23.8
,,	Stronvar	5.75	.2034	25.0
,,	Kippendavie	2.21	.1062	21.0
,,	Crieff	2.29	.1118	20.2
,,	Perth	1.59	.0842	15.2
,,	Dalnaspidal	4.33	.1696	21.8
,,	Blair Atholl	1.81	.0906	18.8
Forfar	Kirriemuir	1.55	.0948	15.2
,,	Dundee	1.68	.0750	16.5
,,	Montrose	1.13	.0739	16.3
Kincardine	Fettercairn	1.78	.0936	14.7
Aberdeen	Braemar	1.88	.0968	16.8
,,	Balmoral	1.99	.0904	16.2
,,	Logie Coldstone	1.20	.0845	14.3
,,	Aberdeen	1.68	.0868	15.2
,,	Ellon	1.45	.0814	15.7
,,	New Deer	1.81	.0884	18.5
Banff	Keith Station	1.81	.0923	19.7
Moray	Gordon Castle	1.42	.0814	17.5
,,	Grantown	1.23	.0852	11.7
Nairn	Delnies	1.18	.0682	13.3
Inverness	Alvie Manse	1.41	.0828	14.3
,,	Fort Augustus	3.78	.1211	25.5
,,	Glenquoich	9.75	.3034	27.7
,,	Drumnadrochit	2.08	.0976	15.7
,,	Inverness	1.01	.0735	11.8
,,	Glenfinnan	8.71	.2957	24.3
,,	Arisaig House	4.01	.1721	20.3
,,	Fort William	6.57	.2158	25.7
,,	Loch Maddy	3.30	.1320	21.5
Ross	Strathpeffer	1.66	.0816	15.3
,,	Ardross Castle	1.87	.1055	16.3
,,	Lower Pitkerrie	1.12	.0614	14.3
,,	Braemore House	5.19	.1695	22.7
,,	Bendamph	6.12	.2332	23.7
,,	Applecross Gardens	3.62	.1569	20.7

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are repeated on the right-hand side to complete the curves. The vertical scale values are indicated by the extremes which are given in each case. Maps of the British Isles showing the month with the highest or lowest average monthly rainfall are given in *British Rainfall* 1920, p. 265. In the west the wettest month of the year is December, and further east, October. At Nairn the wettest month is August. The month with the least rainfall is usually

Mean Deviation of Average Monthly Rainfall as per cent. of Mean Monthly Fall.
0 50 100
SCALE OF MILES.
SCALE OF TINTS.
25 20 15 %
BRITISH RAINFALL.

FIG. 2.

six or seven months earlier, generally April. It is May in the south-west of England, north-west of Ireland and parts of the west of Scotland; March in central England and June in the north of Scotland. The secondary minimum in September is well marked at all stations except Nairn, while there is generally a secondary maximum in August or July. The variation over the country is illustrated by the diagram Fig. 3. As previously explained, the values are based on the mean rain per day and are independent of the varying length of the months.

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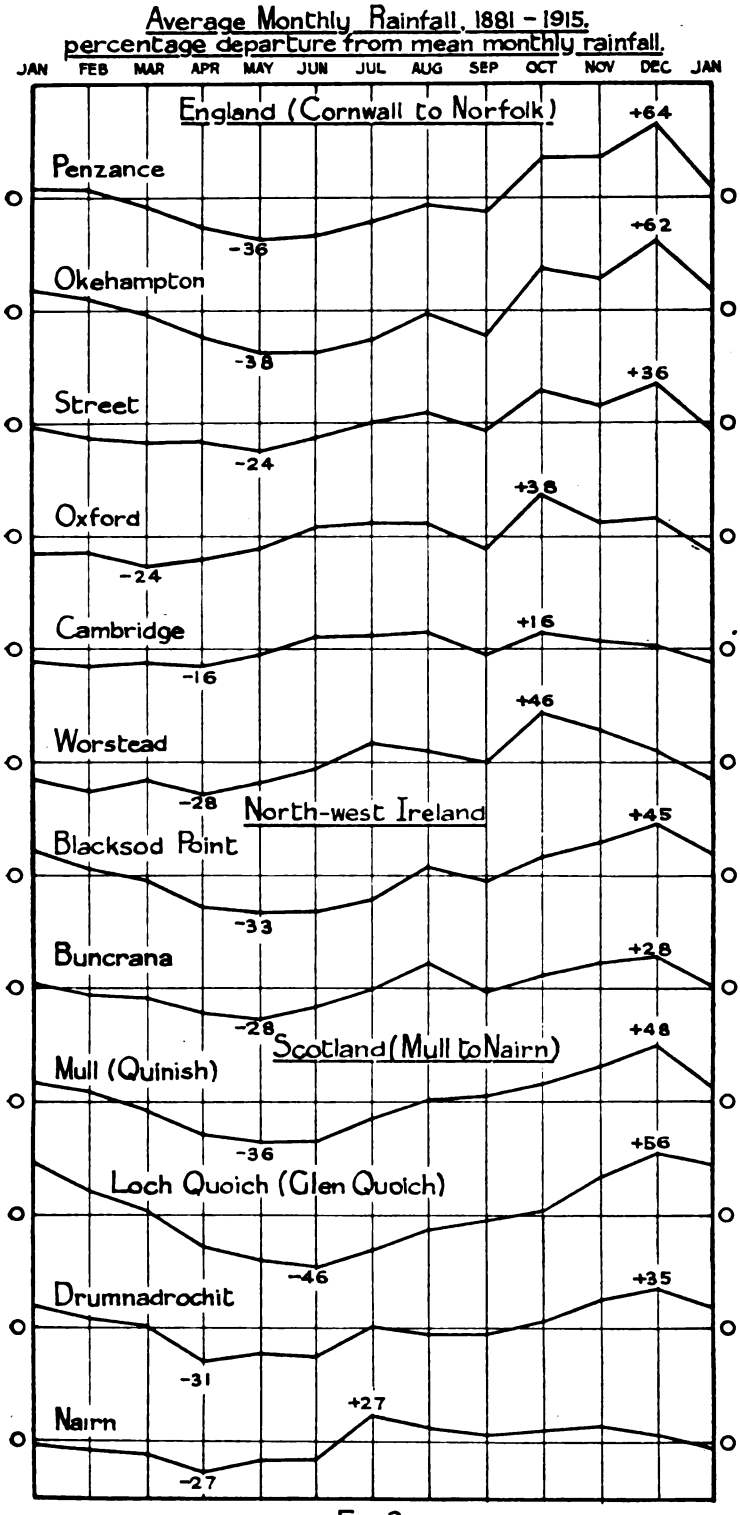

Fig. 3.

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§4. The relation of the variability of average monthly rainfall to the mean rainfall per day.

The stations have been classified according to the mean rainfall per day and the corresponding values for the variability given in Table I. also noted. The mean of the values for each group is given in the table below (Table III.).

TABLE III.—Classification of the values given in Table I. according to the mean rainfall per day.

Mean rainfall per day (ins.)	Less than .0639	.0640 to .0699	.0700 to .0799	.0800 to .0899	.0900 to .0999	.1000 to .1199	.1200 to .1699	Greater than .1700
Equivalent average annual rainfall (ins.).	Less than 23	23 to 26	26 to 29	29 to 33	33 to 36	36 to 44	44 to 62	Greater than 62
No. of Stations	19	40	55	61	45	56	55	19
Group Means. Mean rainfall per day (ins.)	.0608	.0675	.0749	.0851	.0939	.1091	.1407	.2261
Group Means. Equivalent average annual rainfall (ins.)	22	25	27	31	34	40	51	83
Group Means. Mean deviation (per cent.)	16.0	15.8	16.3	16.0	17.3	17.5	20.5	22.9
Group Means. Range (ins.)	1.25	1.32	1.53	1.70	1.98	2.28	3.41	6.27

It is apparent that while the range increases steadily with the annual rainfall, the percentage mean deviation only increases in the last four columns. For groups of stations with a mean annual rainfall of 22, 25, 27 and 31 inches respectively, the value of the percentage mean deviation is about 16 per cent. in each case. The 55 stations in Table I. with an annual rainfall between 44 and 62 inches give a mean value of 20 per cent., and the 19 wettest stations in Table I. a mean value of 23 per cent. for the mean deviation.

The steady increase in the range with the annual rainfall, shown in Table III., is illustrated in Fig. 4, where the values of the range (R) for each group are plotted against the mean rainfall per day (M), the equivalent values for the average annual rainfall being indicated below. The line joining these points is approximately given by the equation $R = -.144 + 18.7\,M + 40.9\,M^2$, and the line represented by this equation is shown on the diagram Fig. 4, which has been extended beyond the values given in Table III. The values for the individual stations given in Table I. are indicated in Fig. 4 by dots, while the values for each group set out in Table III. are shown by crosses. For all practical purposes M can be taken as the average annual rainfall divided by 365.

§5. Variability of average monthly rainfall at some long period stations compared with that for the 35 years 1881 to 1915.

So far, the average rainfall has been considered only for the 35 years 1881 to 1915, and it is of interest to know whether the variability of average monthly rainfall is similar for longer periods.

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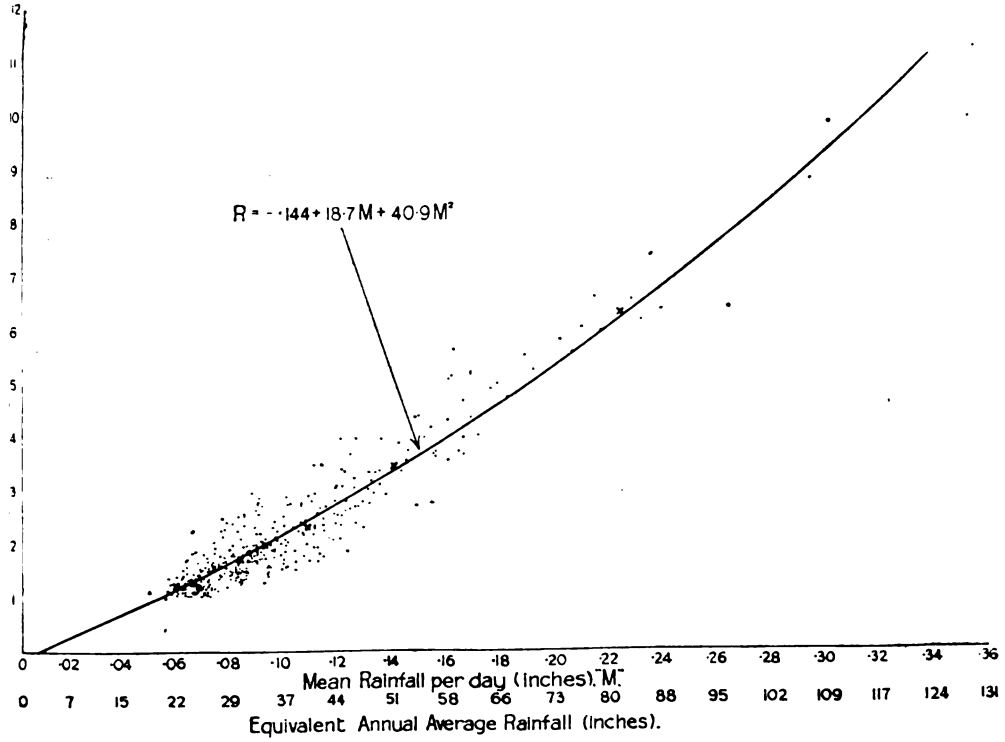

Fig. 4.

For four stations details are given for the longest period of available data alongside similar information extracted from Table I. Two stations, viz., Greenwich and Spalding, are situated in the dry area of the east of England, while the remaining two, viz., Seathwaite and Glenquoich, are wet stations in the west of Great Britain. The difference in the rainfall is indicated by the mean rainfall per day at the two pairs of stations :—

TABLE IV.—Comparison of the variability of average monthly rainfall for long periods with that for 35 years 1881 to 1915.

Station and County.	Greenwich, London.		Spalding, Lincoln.		Seathwaite, Cumberland.		Glenquoich, Inverness.	
Period.	1881–1915.	1815–1921.	1881–1915.	1829–1921.	1881–1915.	1845–1921.	1881–1915.	1868–1924.
No. of Years.	35	107	35	93	35	77	35	57
Difference between greatest and least average monthly rainfall (ins.)	1.06	1.07	1.09	1.10	9.82	9.02	9.75	8.46
Mean rainfall per day (ins.)	.0643	.066	.0643	.0670	.3546	.3610	.3034	.3136
Mean deviation of monthly rainfall (per cent.)	14.2	13.3	16.0	14.5	22.0	22.7	27.7	22.8

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At the two dry stations the mean rainfall per day is about 3 per cent. less in the case of the 35 years, the range of the monthly rainfall in inches is a trifle less, while the mean deviation is about 8 per cent. more. The effect of the longer period is therefore to smooth out the irregularities in the monthly rainfall. At the two wet stations the mean rainfall per day is again less in the case of the 35 years by about the same amount, the range of the monthly rainfall in inches is appreciably more, while the mean deviation is a trifle less in the case of Seathwaite and considerably more in the case of Glenquoich. Details of the changes in the largest and smallest monthly averages for the two periods are indicated below (Table V.).

TABLE V.—Comparison of extreme monthly averages for the 35 years 1881 to 1915 and for long periods.

	Seathwaite.				Glenquoich.			
	Largest average.		Smallest Average.		Largest Average.		Smallest Average.	
	1881–1915.	1845–1921.	1881–1915.	1845–1921.	1881–1915.	1868–1924.	1881–1915.	1868–1924.
Amount (ins.) .	16.34	15.88	6.52	6.86	14.66	13.92	4.91	5.46
Month . . .	Dec.	Dec.	June.	May.	Dec.	Dec.	June.	June.

So that again the effect of the longer period is to give more uniform monthly averages. This is particularly the case at Glenquoich, where the fall of the spring months is not so much smaller than that of the other months in the case of the longer period.

It is important, therefore, to specify that the diagrams Figs. 1 and 2 are for the 35 years 1881 to 1915, and it appears that, if it had been possible to construct such maps for a longer period, the variability shown thereon would have been somewhat smaller.

Acknowledgment is due to Mr. M. J. Salter, of Mickleton, for the preparation of Table I. of this paper.

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.

County.	Station.‡	Difference. Maximum-Minimum.	Mean Rainfall per Day*	Mean Deviation of Monthly Rainfall.†
ENGLAND.		ins.	ins.	%
London	Greenwich Obsy.	1.06	.0643	14.2
,,	Camden Square	1.09	.0669	13.5
Surrey	Dorking	1.88	.0882	16.5
,,	Kew Observatory	1.25	.0651	15.2
,,	Haslemere	2.39	.0975	19.2
Kent	Tenterden	1.92	.0752	19.5
,,	Dungeness	2.22	.0666	24.2
,,	Folkestone	2.37	.0795	21.7
,,	Broadstairs	1.71	.0649	17.8
,,	Margate	1.57	.0622	17.8
,,	Selling	1.81	.0822	16.3
,,	Edenbridge	1.74	.0840	17.8
,,	Sevenoaks	1.51	.0742	15.0
,,	Rochester	1.39	.0712	15.5
Sussex	Chichester	2.12	.0786	20.0
,,	Patching Farm	2.21	.0842	20.2
,,	Horsham	1.98	.0820	19.0
,,	Brighton	2.34	.0819	22.0
,,	Eastbourne	2.49	.0841	22.2
,,	St. Leonards	2.22	.0776	20.2
,,	Hailsham Vic.	2.49	.0864	22.5
,,	Crowborough	2.42	.0985	20.0
Hants	Ventnor	2.25	.0790	25.5
,,	Totland Bay	2.45	.0779	22.8
,,	Bournemouth	2.51	.0862	22.8
,,	Fordingbridge	2.32	.0866	25.3
,,	Southampton	2.09	.0846	19.3
,,	West Dean	1.88	.0803	18.3
,,	Ovington Rectory	2.16	.0908	18.2
,,	Sherborne St. John	1.75	.0792	16.2
Berks	Wellington College	1.67	.0723	15.7
,,	Newbury	1.68	.0794	16.2
Middlesex	Enfield	1.25	.0677	15.3
Herts	Hemel Hempstead	1.62	.0762	14.5
,,	Bennington House	1.19	.0682	15.3
Bucks	High Wycombe	1.56	.0708	16.3
,,	Newport Pagnall	1.24	.0647	15.3
Oxford	Middleton Park	1.45	.0731	14.5
,,	Magdalen College	1 26	.0651	16.5
Northants	Wellingborough	1.03	.0664	12.8
,,	Oundle	1.07	.0610	14.8
Hunts	Waresley Park	1.31	.0655	16.8
,,	Whittlesea Mare	1.25	.0584	18.3
Cambridge	Cherryhinton	1.08	.0590	10.2
,,	Stretham Engine	1.35	.0579	11.8
,,	Wisbech	1.34	.0628	16.3
Essex	Elsenham	1.19	.0673	14.7
,,	Shoeburyness	1.10	.0516	17.8
,,	Southend W.W.	1.22	.0578	16.5
,,	Bradwell-on-Sea	1.00	.0566	15.8
,,	Chelmsford	1.18	.0615	16.8
,,	Earls Colne	1.17	.0633	15.7
Suffolk	Hawkedon	1.18	.0682	15.2
,,	Ipswich	1.20	.0679	15.7

‡ The full names of the stations with the latitude and longitude of each station are given in the *Book of Normals, Section V., Meteorological Office, London.*

* This is actually the mean of the 12-monthly mean rainfalls per day and may therefore differ slightly from the value obtained by dividing the annual rainfall by the number of days in a year.

† The mean deviation of the monthly mean rainfalls per day for the 12 months in the year, is expressed as a percentage of the value in the previous column.*

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Suffolk	Rendlesham Hall	1.20	.0632	15.3
,,	Bury St. Edmunds	1.21	.0687	15.8
,,	Walsham-le-Willows	1.23	.0691	15.2
,,	Geldeston	1.45	.0647	16.5
Norfolk	Norwich	1.48	.0724	15.8
,,	Bylaugh Park	1.57	.0766	16.3
,,	Dilham	1.74	.0718	18.2
,,	L. Massingham	1.43	.0766	15.5
,,	Blakeney	1.34	.0630	16.3
,,	Swaffham	1.31	.0699	16.5
Wilts	Warminster	2.19	.1009	17.2
,,	Bishops Cannings	1.37	.0829	15.3
,,	Mildenhall	1.51	.0830	15.2
Dorset	Weymouth	2.03	.0766	23.0
,,	Bere Regis	2.68	.0922	24.2
,,	Beaminster	2.72	.1029	21.8
,,	Gillingham	1.97	.0897	17.8
Devon	Holne Vicarage	5.60	.1637	29.2
,,	Torquay	2.58	.0904	24.8
,,	Collumpton	2.27	.0965	19.5
,,	Sidmouth	1.83	.0886	17.2
,,	Lyme Regis	2.19	.0916	19.0
,,	Barnstaple	2.48	.1002	21.5
,,	Arlington Court	3.72	.1471	22.3
,,	Okehampton	3.96	.1274	25.7
,,	Torrington	2.68	.1074	22.2
Cornwall	Redruth	3.95	.1238	24.8
,,	Newquay	2.70	.0909	23.0
,,	Bude	2.52	.0916	22.3
,,	Penzance	3.47	.1120	24.8
,,	St. Austell	3.67	.1255	23.5
,,	Liskeard	3.47	.1166	23.7
,,	Empacombe	2.86	.1007	19.7
,,	Altarnon Vic.	5.05	.1619	26.0
Scilly	Tresco Abbey	2.92	.0893	24.0
Somerset	Chewton Mendip	2.62	.1231	17.2
,,	Street	1.49	.0806	15.2
,,	Milverton	2.32	.1003	19.5
,,	Cothelstone	1.98	.0956	17.8
Gloster	Quedgeley Ho.	1.13	.0763	14.0
,,	Cheltenham	1.04	.0724	13.7
,,	Clifton	1.72	.0942	16.5
,,	Fairford	1.15	.0701	15.8
,,	Sherborne Ho.	1.47	.0838	15.0
Hereford	Ross	1.40	.0772	13.3
,,	Kington	1.78	.0898	17.2
Shropshire	Bishops Castle	1.66	.0848	16.2
,,	Preen Manor	1.55	.0795	16.3
,,	Shifnal	1.21	.0715	14.7
Stafford	Market Drayton	1.57	.0789	16.2
,,	Rodbaston	1.20	.0760	14.7
,,	Tean	1.48	.0870	15.0
Worcester	Lincombe Lock	1.03	.0699	13.8
Warwick	Stratford-on-Avon	1.03	.0654	14.3
,,	Rugby School	1.22	.0699	14.8
,,	Coventry	1.09	.0711	13.3
,,	Farnborough	1.20	.0798	12.3
,,	Birmingham	1.09	.0724	14.0
Leicester	Kibworth Beauchamp	1.15	.0701	16.5

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Leicester	Thornton Res.	1.14	.0716	15.2
,,	Belvoir Castle	1.17	.0686	14.7
Rutland	Market Overton	1.33	.0733	15.0
Lincoln	Spalding	1.09	.0643	16.0
,,	Boston	1.39	.0624	16.3
,,	Rauceby Hall	1.19	.0692	14.3
,,	Skellingthorpe Hall	1.17	.0632	15.8
,,	Skegness	1.40	.0637	16.3
,,	Louth	1.57	.0765	15.0
,,	Market Rasen	1.39	.0697	17.2
,,	Brigg	1.42	.0694	16.8
Nottingham	Strelley Hall	1.17	.0698	14.3
,,	Hodsock Priory	1.16	.0645	14.5
Derby	Mickleover	1.07	.0712	15.2
,,	Belper	1.33	.0812	13.7
,,	Hardwick Hall	1.49	.0862	13.0
Cheshire	Runcorn	1.87	.0854	17.0
,,	Altrincham	1.71	.0917	15.7
,,	Woodhead Res.	2.24	.1303	15.0
,,	Buglawton Vic.	1.58	.0833	14.3
,,	Bidston Observatory	1.64	.0763	17.3
,,	Neston	1.58	.0747	18.2
Lancashire	Bury (Gin Hall)	2.35	.1194	15.7
,,	Burnley (Swinden)	2.08	.1212	15.3
,,	Stonyhurst College	2.35	.1273	15.3
,,	Wigan W.W.	1.87	.0967	16.3
,,	Southport	1.69	.0875	18.0
,,	Holker Hall	2.32	.1217	17.2
,,	Monk Coniston	6.50	.2296	22.8
,,	Blackpool	1.84	.0914	18.0
,,	Grizedale Res.	2.51	.1192	17.3
Yorks, W.R.	Sedbergh	2.06	.1493	16.5
,,	Sheffield	1.53	.0832	13.0
,,	Goole	1.24	.0626	17.5
,,	Huddersfield	1.70	.0929	14.0
,,	Garforth	1.24	.0677	14.8
,,	Bradford	1.47	.0858	14.0
,,	Malham Tarn	2.74	.1573	16.0
,,	York Museum	1.18	.0664	15.5
,,	Skipton	1.68	.0899	16.3
,,	Arncliffe Vic.	3.65	.1670	20.8
,,	Wetherby	1.27	.0724	13.8
,,	Harrogate	1.43	.0836	13.2
,,	Pateley Bridge	1.98	.1093	18.3
,,	Ripon	1.45	.0827	13.2
Yorks, E.R.	Patrington	1.51	.0637	19.5
,,	Hull	1.42	.0694	16.8
,,	Market Weighton	1.53	.0764	15.5
,,	Lowthorpe	1.58	.0723	17.0
Yorks, N.R.	Leyburn	1.74	.0893	17.0
,,	Felixkirk	1.21	.0725	16.0
,,	Rounton Grange	1.48	.0699	17.8
,,	Scarborough	1.54	.0714	16.3
,,	Whitby	1.41	.0676	16.3
,,	Lockwood Res.	2.26	.0903	19.7
,,	Middlesbrough	1.70	.0646	20.7
,,	Mickleton	1.63	.0906	15.3
Durham	Darlington	1.23	.0687	13.5
,,	Barnard Castle	1.40	.0813	12.5

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Durham	Wolsingham	1.77	.0909	14.2
,,	Durham Observatory	1.83	.0672	18.8
,,	Sunderland	1.53	.0699	17.0
Northumberland	Newcastle	1.61	.0743	15.5
,,	Hallington	1.58	.0772	16.5
,,	Cockle Park	1.76	.0784	16.5
,,	Rothbury	2.02	.0923	15.0
,,	Biddleston Hall	1.97	.0930	15.8
,,	Howick Hall	1.79	.0771	16.5
,,	Lilburn Tower	1.60	.0764	14.8
,,	Coldstream	1.78	.0817	17.2
Cumberland	Aspatria	2.30	.1120	16.8
,,	Carlisle	2.16	.0920	16.2
,,	Seathwaite	9.82	.3546	22.0
,,	Whitehaven	2.21	.1156	17.8
Westmorland	Kirkby Stephen	2.69	.1159	19.3
,,	Patterdale Hall	7.34	.2367	26.3
,,	Appleby	2.01	.0959	16.7
WALES.				
Monmouth	Llanfrechfa Grange	2.63	.1160	19.2
Glamorgan	Ystalyfera	4.87	.1773	21.7
Carmarthen	Carmarthen	3.00	.1321	21.0
,,	Llanwrda	3.71	.1574	20.2
Pembroke	Castle Malgwyn	3.02	.1198	23.7
,,	Stackpole Court	2.69	.1073	23.3
,,	Haverfordwest	3.20	.1268	23.0
Cardigan	Aberystwyth	2.67	.1271	19.0
Brecon	Nanthir Res.	5.12	.1630	27.2
,,	Brecon	4.29	.1615	24.0
Radnor	Nantgwilt	5.14	.1700	24.2
Montgomery	Newtown	1.93	.0957	17.5
,,	Lake Vyrnwy	3.97	.1525	21.8
Flint	Bodfari	1.81	.0750	18.7
Denbigh	Packsaddle Res.	1.84	.0875	16.3
Merioneth	Blaenau Festiniog	6.35	.2656	18.8
,,	Dolgelly	3.54	.1608	19.2
Carnarvon	Llandudno	1.78	.0821	18.0
,,	Glynllivon	3.03	.1225	21.5
Anglesley	Llwydiarth Esgob	2.28	.1041	20.3
Isle of Man	Douglas Cemetery	2.52	.1127	19.8
,,	Clypse Onchan	2.50	.1201	20.0
Jersey	St. Aubins	2.73	.0916	26.3
Guernsey	St. Peter Port	2.80	.0008	27.2
SCOTLAND.				
Wigtown	Corsewall	2.01	.0933	16.0
,,	Ardwell House	2.00	.0994	17.5
,,	Garliestown	2.36	.1069	18.5
Kirkcudbright	Dalry	4.32	.1193	24.0
,,	Auchencairn	2.77	.1287	17.5
,,	Cargen	2.74	.1226	18.8
Dumfries	Drumlanrig	2.79	.1192	19.5
,,	Moffat	3.89	.1434	23.2
,,	Byreburnfoot	2.41	.1150	17.3
Roxburgh	Branxholme	1.92	.0912	15.0
,,	Kelso	1.38	.0711	16.3
Selkirk	Selkirk	1.38	.0952	14.2
Peebles	North Esk Res.	1.73	.1080	13.5
Berwick	Marchmont Ho.	1.80	.0879	15.0
,,	West Foulden	1.51	.0696	16.2

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Haddington	Prestonkirk	1.84	.0679	20.5
Midlothian	Gladhouse Res.	1.72	.0966	14.0
,,	West Calder	1.88	.0976	14.5
,,	Edinburgh Univ.	1.80	.0711	17.7
Lanark	Cambus Wallace	1.65	.0849	15.2
,,	Glasgow Obsy	2.07	.1017	14.5
,,	Hillend Res.	1.97	.1021	15.3
Ayr	North Craig Res.	2.46	.1128	19.2
,,	Dalmellington	2.73	.1318	18.0
,,	Girvan (Pinmore)	3.10	.1364	19.7
Renfrew	Loch Thom	3.99	.1790	18.8
Stirling	Falkirk	1.94	.0871	16.8
,,	Buchlyvie	2.90	.1377	18.7
Argyll	Glenborrodale	5.49	.1889	22.8
,,	Poltalloch	3.36	.1443	19.5
,,	Campbeltown	3.01	.1234	19.7
,,	Skipness Castle	2.92	.1335	20.8
,,	Inveraray Castle	6.00	.2115	22.0
,,	Islay (Eallabus)	3.31	.1338	20.8
,,	Lismore	3.04	.1196	18.2
,,	Mull (Quinish)	4.16	.1554	20.8
Kinross	Loch Leven Sluice	2.02	.0978	16.3
Fife	Collinsburgh	1.69	.0881	17.0
Perth	Loch Dhu	5.91	.2185	23.8
,,	Stronvar	5.75	.2034	25.0
,,	Kippendavie	2.21	.1062	21.0
,,	Crieff	2.29	.1118	20.2
,,	Perth	1.59	.0842	15.2
,,	Dalnaspidal	4.33	.1696	21.8
,,	Blair Atholl	1.81	.0906	18.8
Forfar	Kirriemuir	1.55	.0948	15.2
,,	Dundee	1.68	.0750	16.5
,,	Montrose	1.13	.0739	16.3
Kincardine	Fettercairn	1.78	.0936	14.7
Aberdeen	Braemar	1.88	.0968	16.8
,,	Balmoral	1.99	.0904	16.2
,,	Logie Coldstone	1.29	.0845	14.3
,,	Aberdeen	1.68	.0868	15.2
,,	Ellon	1.45	.0814	15.7
,,	New Deer	1.81	.0884	18.5
Banff	Keith Station	1.81	.0923	19.7
Moray	Gordon Castle	1.42	.0814	17.5
,,	Grantown	1.23	.0852	11.7
Nairn	Delnies	1.18	.0682	13.3
Inverness	Alvie Manse	1.41	.0828	14.3
,,	Fort Augustus	3.78	.1211	25.5
,,	Glenquoich	9.75	.3034	27.7
,,	Drumnadrochit	2.08	.0976	15.7
,,	Inverness	1.01	.0735	11.8
,,	Glenfinnan	8.71	.2957	24.3
,,	Arisaig House	4.01	.1721	20.3
,,	Fort William	6.57	.2158	25.7
,,	Loch Maddy	3.30	.1320	21.5
Ross	Strathpeffer	1.66	.0836	15.3
,,	Ardross Castle	1.87	.1055	16.3
,,	Lower Pitkerrie	1.12	.0614	14.3
,,	Braemore House	5.19	.1695	22.7
,,	Bendamph	6.12	.2332	23.2
,,	Applecross Gardens	3.62	.1569	20.7

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TABLE I.—Details of the Variability of Average Monthly Rainfall, 1881-1915.—*Continued.*

County.	Station.	Difference. Maximum-Minimum.	Mean Rainfall per Day.	Mean Deviation of Monthly Rainfall.
		ins.	ins.	%
Ross	Glencarron Lodge	6.32	.2403	22.3
,,	Stornoway	3.93	.1366	24.8
Sutherland	Dunrobin Castle	1.40	.0866	11.5
,,	Tongue	2.90	.1123	20.3
,,	Loch More (Achfary)	5.54	.2076	21.3
Caithness	Wick	1.34	.0819	13.3
IRELAND.				
Cork	Dunmanway	4.65	.1672	23.2
,,	Cork	2.87	.1095	21.3
,,	Ballinacurra	2.76	.1105	22.3
,,	Mallow	2.70	.1021	22.0
Kerry	Killarney	4.37	.1499	24.7
,,	Kenmare	5.22	.1933	23.0
,,	Valencia	3.66	.1561	20.0
Waterford	Waterford	2.37	.1080	17.5
,,	Clonmel	2.32	.1143	17.8
Tipperary	Castle Lough	2.16	.1081	16.7
,,	Cashel	2.05	.1021	18.2
Limerick	Foynes	2.40	.1086	18.2
Clare	Miltown Malbay	2.63	.1250	16.8
Wexford	Longraigue	2.38	.1076	15.2
,,	Ballyhyland	2.10	.1170	15.3
,,	Courtown House	1.63	.0949	16.2
Kilkenny	Lavistown House	1.25	.0845	14.2
Wicklow	Coollattin Gardens	1.74	.1146	14.7
Carlow	Carlow	1.27	.0934	14.3
Queens	Blandsfort	1.52	.1000	13.0
Kings	Birr Castle	1.66	.0890	14.7
Kildare	Straffan House	1.79	.0857	15.2
Dublin	Fitzwilliam Square	1.15	.0748	13.7
,,	Ardgillan	1.45	.0792	16.3
Meath	Moynalty	1.63	.1008	12.2
Westmeath	Athlone	1.70	.1012	12.5
,,	Mullingar	1.80	.0994	13.0
Louth	Dundalk	1.51	.0842	12.8
,,	Greenore	1.33	.0873	12.8
Galway	Ballynahinch	3.96	.1669	19.2
,,	Tuam	2.48	.1206	16.7
,,	Woodlawn	2.13	.1128	15.3
,,	Ballinasloe	1.57	.1004	14.0
Roscommon	Strokestown	1.55	.0957	13.5
Mayo	Enniscoe	3.55	.1458	19.5
,,	Blacksod Point	3.33	.1360	21.2
,,	Cranmore	3.16	.1333	19.0
Sligo	Markree Observatory	2.07	.1191	13.8
Cavan	Belturbet	1.43	.0947	11.7
Armagh	Armagh	1.52	.0868	11.5
,,	Newry	1.64	.1044	12.3
Down	Seaforde	1.50	.1048	12.5
,,	Donaghadee	1.32	.0856	12.8
,,	Banbridge	1.45	.0847	13.5
Antrim	Belfast	1.44	.0947	13.8
,,	Dundarave	1.83	.1019	15.8
,,	Ballymena	1.80	.1136	12.8
Londonderry	Garvagh	1.86	.1234	13.2
,,	Limavady	1.56	.1012	12.8
Tyrone	Cookstown	1.68	.1131	12.0
,,	Omagh	1.68	.1098	12.8
Donegal	Malin Head	1.55	.0875	15.3
,,	Buncrana	1.92	.1122	14.5
,,	Dunfanaghy	2.58	.1231	17.0
,,	Killybegs	3.70	.1656	17.0
,,	Convoy House	2.65	.1275	16.3

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DISCUSSION.

Captain W. N. McCLEAN said that he wished to emphasize that the diagrams of Fig. 3 showed that in every case seasonal variation in rainfall existed, for in most cases there were six months of deficiency followed by six months of excess. He thought that the method of plotting these diagrams was a little misleading and that the deviation should have been shown as a horizontal line for each month. He referred to the quotation Dr. Glasspoole had made from an earlier paper. Dr. Mill went on to say: "He could not help wondering whether a coefficient of standard deviation could really give any adequate expression of a curve of nature which average seasonal variation gives. Seasonal rainfall is bi-phased." Captain McClean thought that the figures of mean deviation did not express quite properly this bi-phase. The mean monthly deviation takes no account of the order in which the wet and dry months occur and may therefore give the same deviation for quite dissimilar cases. The year is a very definite cycle, and during that cycle very definite things happen, such as summer and winter, with long days and short days and differences in evaporation. To compare the rainfall of one year with another is to compare similar cycles, but to compare that of one calendar month with a different calendar month is to compare quite different things. By the consideration of seasonal variation there is obtained the actual deficiency from the average which is likely to occur during the year, and this is not directly obtainable from either of the methods given in Table I.

Captain McClean also thought that it would have been of more interest to have had the figures of Col. 3, Table I., expressed as percentages of the average, in order to compare them with the values in Col. 5 of the same table.

He demonstrated by means of diagrams that there were considerable differences between the seasonal variations at different stations. The cases taken were Glenquoich, in the Western Highlands of Scotland, with its very definite high seasonal variation; Nairn, on the East Coast, with an equally definite but lower variation of a different type; and Greenwich, with a shorter dry season. Captain McClean thought that Dr. Glasspoole's research work must be of great value and he made the criticisms because he thought that a monthly deviation could not with advantage be expressed independently of seasonal variation.

Mr. BONACINA said that the orographic factor, which was writ large on the map, was the determining factor in the contrast in question. Even within the limits of a single county, viz., Inverness-shire, one had Inverness with a rainfall similar in amount to that of London with a similar small range, and Fort William with a large rainfall and correspondingly large range. These wet mountain areas had a heavy winter rainfall with a maximum usually in December, just the season when orographic influences were most powerful. So powerful indeed was the winter orographic factor in mountain districts that in the north-west of England it converted an August maximum in the low country outside the Lake District into a December maximum in the heart of the hills, leaving only a secondary maximum in August.

He could not support Captain McClean's remarks about using seasons instead of months, and thought that Dr. Glasspoole was perfectly right in using months to show the course of the annual variation of rainfall. The seasonal variation of rainfall in the British Isles was

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extremely complex, and to deal with the matter seasonally one could not treat rainfall as a totality, but would have to analyse it into different component types.

Finally, Mr. Bonacina thought it worth while to point out that the fact of the larger seasonal range in average rainfall occurring in the wet regions, where even the driest month was wet, rendered it climatically unobtrusive. If so large a range were to occur in the drier parts of England, it would mean that during the dry season the general humid character of the English climate would be lost.

The following contributions to the discussion were read:—

Dr. H. R. Mill: The fuller discussion of variability of rainfall based on more abundant data of more recent date shows that the distribution found by Mr. Comissopulos in 1916 was substantially correct. The results must still be taken with some reserve, however, because of the undoubted tendency for the mean monthly rainfall at individual stations to change with the lapse of time as Dr. Glasspoole shows in his discussion of the four long records. I am pleased to see the rainfall computed in such a way as to eliminate the effect of months of unequal length, as the data are thus more fairly presented than in the isomeric maps which Mr. Salter and I brought before the Society in 1915. Accepting the map (Fig. 2) as representing with substantial accuracy the distribution of variability in normal monthly rainfall, we are faced with the problem of its interpretation. If we examine the obvious suggestion that the configuration of the land determines the variability of monthly distribution, as well as that of monthly total rainfall, we are confronted with the absence of a high percentage on the mountains of south-east and north-east Ireland, though this may be due to the absence of typical mountain stations from the selected list. A more difficult case is the prevalence of variability over 20 per cent. along the South Coast of England, while a lower variability prevails over the hilly country of the Downs and the Chilterns. Perhaps the small scale of the map may in part account for this, but that cannot be taken as a sufficient reason. The influence of exposure to oceanic winds is the cause of the orographic control of rainfall distribution, and while the new map of variability does not seem to throw any fresh light on this question, it does not contradict the conclusion which Mr. Salter and I deduced from the twelve isomeric maps that the variability of monthly prevailing winds acting on the invariable configuration determines the distribution of the mean monthly rainfall of the British Isles both in space and time. The general map would necessarily throw into prominence the regions of high rainfall with the most frequent winds and blur the effects produced by winds from other quarters even though these might form a large proportion in individual months.

Mr. A. A. Barnes: The fact that the range of monthly rainfalls was directly related to the long-average annual rainfalls was noticed by the writer when *The Book of Normals, Section* 1, was published in 1919, and he attempted to find a formula which would represent that relation. The formula evolved was an exponential equation and of quite a different form to that now given by Dr. Glasspoole. Converting it to the same units in inches, so that R represents the monthly range and M represents the mean rainfall per day, the formula was as follows:—

$$R = 37\ M^{1.23}$$

This equation was easily calculated logarithmically, and the plottings of

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log R against log M gave a straight line which ran through the middle of the observed points.

It is of interest, therefore, to test this formula against Dr. Glasspoole's groupings in Table III. of the present paper, the result being :—

TABLE I.—Relation between Annual Rainfalls and Monthly Ranges, as given by Formula $R=37M^{1.23}$. (Grouped as in Table III.)

Average Annual Rainfall.	Mean Rainfall per day M.	Range of Monthly Averages R.	Calculated. R.
Inches.	Inches.	Inches.	Inches.
22	.0608	1.25	1.18
25	.0675	1.32	1.34
27	.0749	1.53	1.53
31	.0851	1.70	1.79
34	.0939	1.98	2.02
40	.1091	2.28	2.43
51	.1407	3.41	3.32
83	.2261	6.27	5.94

It will be observed that between the limits of 25 and 51 inches, which practically comprised all readings which the writer dealt with near the Southern Pennines, the agreement is quite satisfactory, though no doubt Dr. Glasspoole's present formula is far more accurate.

With reference to Tables IV. and V. the writer cannot help repeating his objection to the 35 years 1881 to 1915 having been adopted as a *standard* long-average period. Surely gauges that have been read for 57, 77, 93 or 107 years as shown in Table IV. should give *some* indication as to whether an adopted period gives a fairly representative long-average figure or not, and yet it is found in Table IV. that 1881 to 1915 gives only 97, 96, 98 and 97 per cent. respectively of the mean rainfalls over those long periods. In other words, as pointed out previously,[1] our present standard gives a long-average figure which is far too low for individual gauges. The writer realises that destructive criticism is useless unless a remedy is suggested, but he would mention that eleven years have elapsed since 1915. Most of those years have been wet. A dry cycle finished and a wet cycle commenced at the end of 1908, and that almost any period symmetrical about the end of 1908—such as 1891 to 1925—is therefore preferable to the present standard.

Mr. G. R. Collinson, M.Inst.C.E., writes: While Dr. Glasspoole's analyses of the variability of *average* monthly rainfall form a suitable introduction to those engaged in examining water statistics in relation to sources of existing and future water supplies, he thought that it was *minimum* values which were of more concern to the water engineer than averages. He considered that it would be of great practical utility if ratios between the minimum rainfalls of groups of a number of consecutive months and the average annual rainfall were available for a number of representative stations with long records. He had taken out such ratios from the Appleby raingaugings extending from 1870 to 1926, and the ratios appear in the table below.

The smallest aggregates of the average monthly rainfall for different numbers of consecutive months are given in column 2 of the table below, and their percentages of the annual average rainfall, namely, 35.03 inches,

[1] *London, Q.J.R. Meteor. Soc.*, **191**, pp. 225 and 226.

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are stated in column 4. Column 5 gives the minimum aggregates that have ever been recorded for various numbers of consecutive months over the period from 1870 to 1926, and these aggregates are expressed as percentages of the average annual rainfall in column 7.

TABLE I.—RAINFALL AT APPLEBY, WESTMORLAND.

Number of consecutive months.	Lowest aggregate average monthly rainfalls from Book of Normals, 1881-1915.		Lowest aggregate average monthly rainfalls as percentages of annual average (35.08 in.)	Minimum aggregate rainfalls recorded 1870-1926.		Minimum aggregate rainfalls, 1870-1926, as percentages of annual average (35.08 in.).
	Inches.	Period.		Inches.	Period.	
1	2	3	4	5	6	7
2	4.15	April-May	11.8	1.37	Feb.-Mar., 1891	3.9
3	6.44	April-June	18.4	2.21	Feb.-April, 1891	6.3
4	9.12	Mar.-June	26.0	4.15	Feb.-May, 1875	11.8
5	12.08	Feb.-June	34.5	5.43	Feb.-June, 1891	15.5
6	15.24	Feb.-July	43.3	6.71	Dec. 1890 to May, 1891	19.1
7	18.44	Jan.-July	52.7	8.86	Dec. 1890 to June, 1891	25.2
8	21.74	Jan.-Aug.	62.1	13.04	Jan.-Aug., 1887	37.2
9	24.27	Jan.-Sept.	69.3	16.37	Oct. 1879 to June, 1880	46.8
10	27.75	Jan.-Oct.	79.3	18.67	Feb.-Nov., 1873	53.2
11	31.07	Jan.-Nov.	88.7	20.10	Feb.-Dec., 1873	57.4
12	35.03	Jan.-Dec.	100.0	22.91	Mar. 1887 to Feb., 1888	65.5

The percentages given in columns 4 and 7 have been plotted and are shown on the diagram (Fig. 1), the dotted line indicating the probable minimum percentages if records over a longer period could have been examined. An example will show the practical use to which such a curve can be put.

The dry weather flow from a large catchment area in Teesdale was found in 1901 to average 0.33 cubic feet per second per thousand acres over a period of five consecutive months of low rainfall, May to September, during which 8.06 inches were registered in the raingauge. The latter represents 22.7 per cent. of the average annual rainfall in that case, namely, 35.5 inches, whereas the Appleby curve shows that over a period of five months the minimum rainfall was 15.5 per cent. of the annual average. Applying this percentage to the rainfall of the Teesdale catchment area, one finds a probable minimum rainfall of 5.50 inches as against that of 8.06 inches recorded for the five months of 1901. With the former minimum rainfall it is obvious that the dry weather flow would be lower than that measured in 1901, and although it is not the present purpose to calculate the probable *minimum* dry weather flow, it is clear that the latter could not be evaluated unless the probable minimum rainfall were ascertained as described above.

One has had to assume in the present case that the Appleby variations are typical of those in the Teesdale catchment area, but if a sufficiently large number of records were examined a series of maps for the whole country could be prepared showing lines of equal minimum

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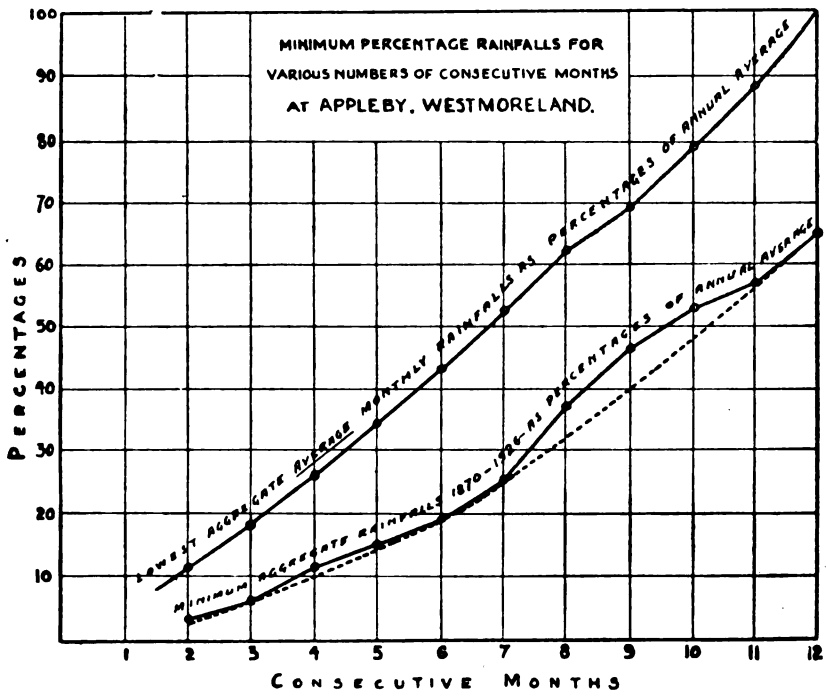

FIG. 1.

rainfall for periods consisting of different numbers of consecutive months, and such maps would be of the utmost value when calculating rates of *minimum* dry weather flow from records of flow taken under known conditions of rainfall higher than the minimum.

He thought that waterworks engineers were particularly grateful to Dr. Glasspoole, and that such an appreciation could not be more highly expressed than by the Oliver Twist principle of "asking for more."

Dr. GLASSPOOLE, in reply, agreed with Captain McClean that the paper aimed at defining the variability of the average monthly rainfall, irrespective of the incidence of the dry and wet months, which was only touched on in Fig. 3. The differences in the rainfall of the seasons to which Captain McClean referred were emphasized when considered in conjunction with the evaporation, and it was the "effective rainfall" for water supply, rather than the rainfall itself, which differed so in summer from that experienced in winter.

As to the use of averages for other periods, he thought that in order to prepare comparable statistics in successive investigations it was important to use the same average. Averages of the 35 years, 1881 to 1915 were now common, and the relation of the rainfall of that period to other periods was known. He was doubtful, however, if any period would serve as the standard indefinitely.

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Rainfall in the Southern Pennines.

Two pamphlets have just been published dealing with the rainfall over the Southern Pennines,[1] an area including the ridge of moorland from the Peak District to Pendle Hill, and the plains on the west to the coast from Blackpool to the mouth of the Dee, and on the east to Leeds and Chesterfield. They are numbers 14 and 15 of a series of which the first number was a modest two-paged publication giving the rainfall of August and September, 1917. During 1918 a map showing the configuration of the land was included and subsequently a map of the annual rainfall of 1917. The rainfall of the years 1918 to 1924 has been dealt with on similar lines in numbers 9 to 15, each containing seven tables and two maps. The latter show the actual rainfall and the fall expressed as a percentage of the average for the years 1865 to 1908. The reasons for the choice of this period for the average are set out in a paper read by Mr. Barnes before the Royal Meteorological Society in July, 1919. The annual maps are reproduced on a scale of ten miles to one inch, and in most cases the isohyetal lines are drawn at intervals of five inches.

In each of the last seven numbers annual values for eight stations are given covering the period from 1865 to date, so that in all 56 long period records have at present been published. The values are also given as percentages of the average. Additional averages have been computed year by year for the remaining records, and averages for 300 stations are now published. The 1924 issue gives annual totals for some 360 stations, together with the available averages and the corresponding percentage values. In certain cases where records have terminated, the annual percentages have apparently been estimated from the maps and the probable annual rainfalls computed. In tables where such values are included it should be stated clearly that they are not deduced from actual observations.

The whole area is divided into 25 rectangles of sides fifteen by ten miles. The annual general rainfall in inches, expressed also as a percentage of the average, is given for each area, together with the monthly general rainfall in inches and their percentages of the yearly rainfall.

The annual values are plotted on working charts on the scale of two miles to one inch and submitted to a close examination. In the issue for 1924 nine percentage values are queried, whereas it would have been more logical to query either the rainfall or the average. In drawing the isohyetal lines for some years insufficient weight seems to be given to the relation between land configuration and rainfall. Probably Kinder Scout receives more rain than is indicated, although there are no rain-gauge measurements to support this contention.

This detailed study of the rainfall of an area of extensive moorlands cannot fail to be of value in the consideration of problems related to the water supply of the adjacent industrial towns.

J. G.

[1] A. A. Barnes, *Manchester and Stockport Rainfall Organisation*, Vol. 1, Nos. 14 and 15, 1923 and 1924, pp. 127-158, with four maps.

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DIFFUSION OVER DISTANCES RANGING FROM 3 KM. TO 86 KM.

By L. F. RICHARDSON, D.Sc., F.R.S., and DENIS PROCTOR.

(*Memoirs of the Royal Meteorological Society*, Vol. I., No. 1.)

[Published June, 1926—Discussed February 16, 1927.]

SUMMARY.

This *Memoir* describes the way in which air is scattered and mixed by the eddies in the wind. In order that the wandering of a piece of air may be observed, the air must have some mark carried with it. Small free balloons have served for this purpose; so has volcano ash. The statistics of the observed scatter may be of interest in connection with factory smoke and town planning. The rate of diffusion has been observed by various authors for air-masses ranging in size from a few metres to 1,000 kilometres, and comparison of their results shows that Fick's law does not describe atmospheric diffusion.

This research was financially supported by the Government Grant Committee of the Royal Society. The balloon records were obtained from Major J. M. MacLulich, of Brighton, and from the League of Nations Union.

DISCUSSION.

Mr. D. BRUNT pointed out that there were some reasons for regarding K as a function of time, for the longer the diffusion continued, the greater the probability of separate balloons getting into different large scale eddies. If the balloons remained up for a sufficiently long time, they might get into the wind systems of more than one depression.

[*Added later.*] It should be noted that K measures the diffusing power of the atmosphere, and that there is no "instantaneous" value of K. It cannot be *assumed* that K is independent of the time over which the diffusion is measured, without adducing some proof that the assumption is justified.

Dr. RICHARDSON [*communicated*]: If in Fick's equation $\partial\chi/\partial t = K\partial^2\chi/\partial x^2$ we take the diffusivity K to be a function of time from the start, it will also be necessary in order to explain observations to regard K as a function of the size and shape of the source. *Note added May*, 1927. A cluster of microscopic particles, placed in still water, spreads by diffusion. The spread may be measured by the standard deviation σ of the particles from a plane drawn through the centre of the cluster. The time rate of increase of σ may be denoted by $\dot{\sigma}$. It has been suggested by Einstein* and observed by Perrin† that the spreading goes on in such a way that:—

$$\dot{\sigma} \text{ varies as } \sigma^{-1} \quad . \quad . \quad . \quad . \quad (1)$$

provided the cluster began as a single small dot.

* Einstein, A., *Ann. der Phys.*, Vol. 17, 1905.
† Perrin, *Atoms* (Constable & Co., 1916).

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For a distribution of any shape, the process is described by Fick's equation

$$\bar{u}\frac{\partial \nu}{\partial x} + \bar{v}\frac{\partial \nu}{\partial y} + \bar{w}\frac{\partial \nu}{\partial z} + \frac{\partial \nu}{\partial t} = \frac{\partial}{\partial x}\left(K\frac{\partial \nu}{\partial x}\right) + \frac{\partial}{\partial y}\left(K\frac{\partial \nu}{\partial y}\right) + \frac{\partial}{\partial z}\left(K\frac{\partial \nu}{\partial z}\right) \quad (2)$$

where ν is the number of particles per volume, t is the time, and x, y, z are rectangular co-ordinates; $\bar{u}$, $\bar{v}$, $\bar{w}$ are mean speeds and K is the diffusivity. This type of diffusion may appropriately be called Fickian.

Very different is the horizontal spreading of smoke particles or of balloons in the free atmosphere. For a cluster that was initially very small we find subsequently that:—

$$\dot{\sigma} \text{ varies roughly as } \sigma^{1/3} \quad . \quad . \quad . \quad (3)$$

The larger the patch the faster it spreads, in contrast with (1). This may be called non-Fickian diffusion.

Ever since Taylor and Schmidt opened up the subject of atmospheric diffusion we have all been attempting to fit the observations into the inappropriate equation (2) with the result that K has been found to vary from 0.2 to 10^{11} cm^2 sec^{-1}. This result is peculiarly unsatisfactory because there is no variable in (2) of which we can suitably regard K as a function, unless it be the period used in forming the averages $\bar{u}$, $\bar{v}$, $\bar{w}$. Instead, K depends upon the size of the cluster, as (1) and (3) show.

Now (3) is too special, for it applies only to clusters that grew from a point. We seek a general description by way of a differential equation. This can be attained by means of a new conception "the average number of neighbours per length."

• • • • • • •

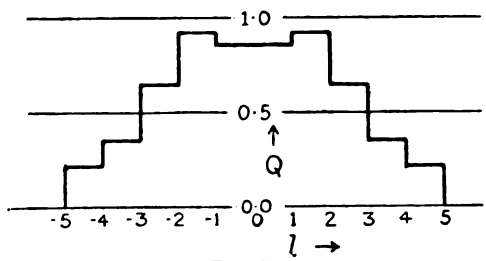

FIG. 1.

In the top part of Fig. 1 are seven dots representing seven people living on a straight road at intervals of 2, 4, 6, 8, 10, 12 tenths of a kilometre. How were they off for neighbours? Take Mr. A, lay off a scale from his house and count how many neighbours he had between 1 and 2 km., between 2 and 3, 3 and 4, and so on. Repeat the counts for Messrs. B, C, D . . . Then take for each range of separation l of 0 to 1, 1 to 2 km., etc., the average number of neighbours. This average Q is the function of l shown in the lower part of Fig. 1.

Here in Fig. 2 is a row of balloons (=molecules) equally spaced initially. Below we see that neighbours are indefinitely common at $l = \pm(1, 2, 3, 4 \ldots)$, but at other separations there are no neighbours. Now the balloons are let loose and wander out of position. The infinities

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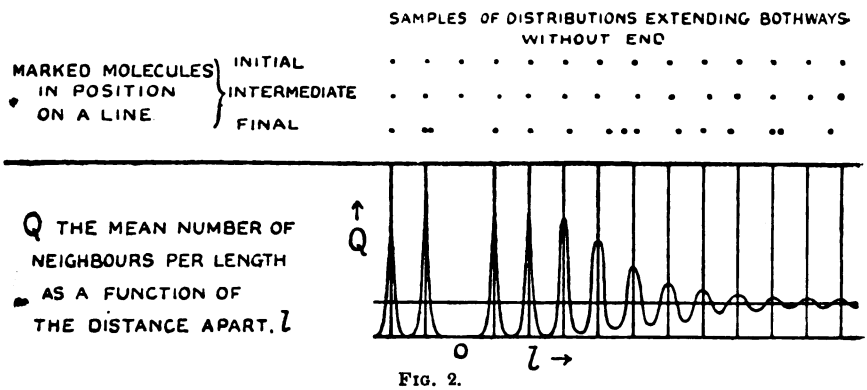
SAMPLES OF DISTRIBUTIONS EXTENDING BOTHWAYS WITHOUT END
MARKED MOLECULES IN POSITION ON A LINE
INITIAL
INTERMEDIATE
FINAL
Q THE MEAN NUMBER OF NEIGHBOURS PER LENGTH AS A FUNCTION OF THE DISTANCE APART, l
Q
O
l →

FIG. 2.

of Q thereupon soften down into peaks with spreading bases. The curve in the diagram is a fiction to suggest this truth. Ultimately the balloons, or rather their geometrical projections on to a great circle of the earth, are distributed at random, and neighbours are equally common at all distances, so that the graph of Q is parallel to the l axis. These successive changes look like a sort of *diffusion* of Q in the l-space. On pursuing this idea it was found that

$$\frac{\partial q}{\partial t} = \frac{\partial}{\partial l}\left\{ F(l)\frac{\partial q}{\partial l} \right\} \quad . \quad . \quad . \quad . \quad (4)$$

and that $F(l) = \epsilon\, l^{4/3}$ approximately. In the range 10 cm $< l <$ 10^8 cm, ϵ varies only between 0.1 and 15. Thus ϵ is 10^9 times less variable than K. The reasoning, the reduction of observations, and the slight distinction between Q and q, will be found in *Proc. Roy. Soc.* (A), Vol. **110**, 1926, pp. 709 to 737, from which the diagrams are taken, by permission of the Royal Society.

Subsequent observations show that F depends not only on l but also on the distance m, n of neighbours in mutually perpendicular directions. If q is the mean number of neighbours per *volume* at (l, m, n) the true description probably is

$$\frac{\partial q}{\partial t} = \frac{\partial}{\partial l}\left\{ \frac{\partial q}{\partial l} F \right\} + \frac{\partial}{\partial m}\left\{ \frac{\partial q}{\partial m} F \right\} + \frac{\partial}{\partial n}\left\{ \frac{\partial q}{\partial n} F \right\} \quad . \quad (5)$$

where $F = F(l, m, n)$.

Library, Science Museum.

The Director of the Science Museum (Colonel Sir Henry G. Lyons, F.R.S.) has sent particulars of new arrangements under which books and periodicals may be borrowed from the Library of the Science Museum. Hitherto, volumes have been readily available only to those who are resident in London, but under the new rules, books, etc., may be obtained on loan for scientific workers through approved institutions on condition that no charge for postage or replacement falls on public funds. Books and journals will not be sent direct to individual workers, but only through the institution to which the applicant belongs.

The Library is open free to the public, practically without restriction. It contains 165,000 volumes, and this number is being increased at the rate of 9,000 volumes a year. Periodicals number about 8,000. Admission is by ticket, obtainable on application to the Director, or for a single admission, to the Keeper of the Library.

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REPORT OF THE COUNCIL

FOR THE YEAR 1926

[Submitted to the Annual General Meeting, January 19, 1927.]

In comparison with its predecessor, in which the 75th Anniversary of the Society's foundation was celebrated, the year 1926 has seemed comparatively uneventful. Nevertheless, several matters of great importance have been the subject of consideration by the Council. Of these the most important are the initiation of the series of *Memoirs*, in which the more technical of the papers accepted by the Society are published; the re-arrangement of the Office Staff; the publication of the "Rainfall Atlas of the British Isles," and the arrangements for six "talks" on meteorological subjects which were broadcast by wireless.

QUARTERLY JOURNAL AND MEMOIRS.—The policy of the Council has been to make the *Quarterly Journal* more attractive to the general body of Fellows, by including in it papers and notes of general interest; and to allot the more technical papers to the new series of *Memoirs*. It is believed from information received that some success has attended this policy. It is worthy of mention that in spite of the publication of five important scientific papers as *Memoirs*, the Journal for 1926 is the largest on record.

The Council are indebted to three Fellows who have for the second time placed at their disposal a sum of £150 in aid of the publication of the *Journal*. The Council made application again this year to the Royal Society for a second sum of £150 from the Government Publication Grant, and are glad to report that the request has been granted. Two amounts of £150 each, for 1925 and 1926, have now been received, and are both shown in this year's accounts.

The publication of the *Memoirs* has thus been made possible. It has been arranged to issue copies of the *Memoirs* to those Fellows who have intimated a desire to receive them. At present about 350 copies are being circulated either to Fellows or to libraries and other institutions.

As already mentioned, five *Memoirs* have been issued and others are in the press.

OFFICE STAFF.—In view of the difficulty which has been experienced by the Staff in completing the work of re-cataloguing the books of the Library, necessitated by the removal from Victoria Street to South Kensington, in addition to the fulfilment of their regular duties the Council have effected a reorganisation of the work of the Office which will tend to efficiency and economy. The Senior Clerk has recently been replaced by a part-time typist, and before her departure marked progress was made with the library catalogue. The card index of authors of books is now practically complete; the subject index remains to be dealt with.

"RAINFALL ATLAS OF THE BRITISH ISLES."—The Atlas, which contains 44 coloured quarto plates and an introduction by Dr. H. R. Mill, has now been published at the price of fifteen shillings.

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Fellows can obtain copies at the reduced price of 10/9 post free, on application to the Assistant Secretary.

Great care has been taken in the preparation and printing of this important work. It is confidently hoped that the Atlas will appeal to a large number of Fellows, water engineers, teachers and students, by reason of its artistic merit as well as by the fact that it forms a standard and authoritative work of reference.

The cost of production is being borne by the British Rainfall Organization Fund of the Society. The Council desire to record their thanks to the Committee and especially to the Secretary, Mr. R. Corless, who has been responsible for the passage of the work through the press.

WEATHER TALKS BY WIRELESS.—By arrangement with the British Broadcasting Company six talks on weather were given as follows:—

Sept. 22. (1) Weather and Plant Life. By I. D. Margary.
,, 29. (2) Rain. By Dr. H. R. Mill, F.R.S.E.
Oct. 6. (3) Atmospherics and the Atmosphere. By R. A. Watson Watt.
,, 13. (4) Thunderstorms. By Dr. G. C. Simpson, F.R.S.
,, 20. (5) Climate. By C. J. P. Cave.
,, 27. (6) Forecasting. By J. S. Dines.

In the course of his talk Mr. Margary referred to the fact that further observers were required for the Phenological Report in stated parts of the country. As a result about one hundred and fifty inquiries were received. It is proposed to publish the text of the talks in future issues of the *Journal*.

MEETINGS.—Eight ordinary meetings have been held in the Society's rooms. At the meeting in April a telegram of congratulation was dispatched on behalf of the Fellows to Mr. R. Inwards, past President, on the occasion of his eighty-sixth birthday. Mr. Inwards has been a Fellow of the Society for sixty-four years.

By kind invitation of Colonel Sir Henry Lyons, F.R.S., Director of the Science Museum, a meeting of the Society was held in the new galleries of the Science Museum on February 3rd. The meeting took the form of a Conversazione and was attended by about forty Fellows and their friends.

In addition to these an informal meeting took place in October to welcome Dr. T. Okada, Honorary Member, Symons Medallist, Director of the Central Meteorological Observatory, Tokyo, who was accompanied by Dr. S. Fujiwhara. At this meeting Dr. G. C. Simpson described a series of lantern slides of clouds recently presented by Mr. G. A. Clarke and Dr. S. Fujiwhara read a paper on Cloud Studies, which will be printed in the *Journal*.

A meeting provisionally arranged to take place in Edinburgh in July had to be abandoned in view of the uncertainty of railway facilities owing to the coal dispute.

PHENOLOGICAL REPORT.—The 35th Report of the New Series was presented to the meeting in June, and in December, 1925, Mr. I. D. Margary read an interesting paper on an old phenological record which had been kept almost unbroken by the Marsham family since 1736. The paper appears on p. 27 of the *Journal* for 1926.

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The Council desire again to place on record their appreciation of the work of Mr. J. E. Clark, Mr. I. D. Margary and Mr. R. Marshall, members of the Phenological Committee.

FINANCE.—The accounts for the year are printed at the end of this Report. The credit balance shown is £506 18s. as compared with £448 12s. at the end of 1925. The Society is beginning to feel the benefit of the reduction of the rate of interest on the Debentures mentioned in last year's Report. The Council continues to be impressed with the desirability of repaying as quickly as possible the debt on the Society's property, and has arranged in 1926 for the redemption of six Debentures, thus reducing the debt to £3,000.

FELLOWS.—Particulars as to the number of Fellows are given in the following table:—

	FELLOWS.			HONORARY MEMBERS.
	ANNUAL.	LIFE.	TOTAL.	
December 31, 1925 - -	**592**	**177**	**769**	**17**
Since elected - - -	+44	—	+44	—
Reinstated - - - -	+ 4	—	+ 4	—
Deceased - - - -	−10	− 9	−19	—
Resigned, etc. - - -	−38	—	−38	—
December 31, 1926 - -	**592**	**168**	**760**	**17**

There is thus no change in the number of Annual Fellows in the course of the year. The table, however, includes ten names which have been removed from the register for non-payment of subscriptions.

The Council record with much regret the deaths of the following Fellows, the dates in parenthesis representing the years of election:—

C. E. de Bertodano (1887).
Rev. H. A. Boys (1900).
J. H. Casartelli (1910).
H. H. R. Chapman (1907).
Capt. M. H. Clarke (1900).
Capt. S. G. Dale (1917).
J. C. Eckersley (1900).
Rev. J. C. Fox (1907).
W. J. Harrison (1890).
Sir Peter Scott Lang (1886).
Lord Lyell (1909).
R. F. McEwen (1909).
Dr. J. G. McKendrick (1866).
A. S. Marriott (1887).
R. E. Middleton (1894).
E. Pullar (1909).
W. J. Howard-Smith (1894).
C. Stoeckel (1910).
Miss E. D. Woodhouse (1907).

PORTRAITS OF PRESIDENTS.—In last year's Report reference was made to a proposal to obtain portraits of all past Presidents from 1850 and to place them in the Society's rooms.

This proposal has now been carried out and the portraits have been suitably framed and hung on the stairway. It is regretted that it has not been possible to obtain portraits of Mr. George Leach, F.R.S., President 1853, and of Dr. Robert Dundas Thomson, M.D., F.R.S., President 1863; otherwise the series is complete.

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MUSEUM.—The Council have decided to start a small museum in the Society's rooms for the exhibition of the historical instruments and other objects of meteorological interest which are in the possession of the Society.

DONATIONS TO THE SOCIETY.—In addition to the contributions from certain Fellows and the grant from the Royal Society towards the cost of the *Journal* and *Memoirs*, the following donations have been received:—

Contributions to the funds of the Society from Dr. G. C. Simpson, F.R.S., Mr. R. Cooke and an anonymous donor.
Lantern slides of clouds from Mr. G. A. Clarke.
Revolving frame for the exhibition of lantern slides from Commander L. G. Garbett, R.N. (retd.).
Books of historical interest from Dr. S. Fujiwhara and Dr. C. P. Hooker.
Current books and periodicals, as listed in Appendix II.

AWARDS:—*The Buchan Prize.*—The second award of this prize has been made to Mr. C. K. M. Douglas, B.A., the author of the following papers which have appeared in the *Journal* during 1922 to 1925:—(1) "Observations of Upper Cloud Drift as an Aid to Research and to Weather Forecasting"; (2) "Further Researches into the European Upper Air Data, with Special Reference to the Life History of Cyclones"; (3) On the Relation Between the Source of the Air and the Upper Air Temperature up to the Base of the Stratosphere."

The Howard Prize, consisting of an aneroid barometer, suitably inscribed, was awarded to Cadet B. N. Harman, of H.M.S. "Worcester," for an essay entitled, "The Distribution and Causes of Fog over the North Atlantic Ocean."

COMMITTEE ON ATMOSPHERICS.—On the recommendation of the Committee (appointed to investigate the relation between atmospherics and weather), and by arrangement with the British Broadcasting Company, a circular was issued to Fellows inviting their co-operation in a scheme for determining the range of atmospherics. The results of this work will be printed in the *Journal*. A sum of £20 has been allotted from the Research Fund to meet the expenses in connection with this investigation.

COMMITTEE FOR THE PROMOTION OF THE STUDY OF RADIATION.—At the request of the British Association Committee for the Investigation of the Upper Atmosphere, five Fellows of the Society were appointed as members of a joint committee for the promotion of the study of radiation. A sum of £17 was allotted from the Research Fund towards the purchase of a radiation recorder by Gorczynski, which has been placed in charge of Mr. C. S. Leaf, at Cambridge.

MISCELLANEOUS.—During the year the Council acceded to a request for the loan of photographs for exhibition at the Eastbourne Popular Scientific Exhibition. These photographs attracted much interest.

LECTURE AT EALING.—At the request of the Ealing Scientific Society, Mr. R. Corless lectured before them on March 13th, his subject being "Squalls and Storms."

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APPENDIX

STATEMENT OF RECEIPTS AND PAYMENTS

RECEIPTS.

	£ s. d.	£ s. d.
Balance from 1925—Cash at Bank of England	248 12 0	
Deposit at Westminster Bank	200 0 0	
		448 12 0
Subscriptions for 1926	1351 3 0	
,, ,, former years	74 18 0	
,, ,, 1927	48 2 0	
		1474 3 0
Entrance Fees		38 17 0
Dividends and Interest		57 18 2
Sale of Publications, Advertisements, etc.		256 2 8
Rent of Maisonette (*less* Income Tax recoverable, £45)		180 0 0
Contribution for administrative purposes from British Rainfall Organization Fund		10 0 0
Contributions from Fellows to the General Funds		15 15 0
Contributions from Fellows to *Journal* Fund		151 0 0
Contributions from the Government Publication Grant for expenses in aid of publications—		
Grant for 1925	150 0 0	
,, ,, 1926	150 0 0	
		300 0 0
		£2932 7 10

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I.

FOR THE YEAR ENDING DECEMBER 31, 1926.

PAYMENTS.

	£ s. d.	£ s. d.
Debentures.—		
Redemption of six Debentures	300 0 0	
Interest paid on Debentures	191 8 8	
		491 8 8
Journal, etc.—		
Quarterly Journal, Nos. 216-219	434 14 7	
Illustrations	66 4 4	
Reprints of Papers	64 14 6	
Reviews	10 5 0	
Memoirs, Nos. 1-5	120 2 0	
Assistance in preparation of publications	80 0 0	
Bibliography of Meteorological Literature, Nos. 9 and 10 ...	58 17 6	
Monthly Weather Reports, 1925	20 11 2	
		855 9 1
Printing, etc.—		
General Printing	56 15 3	
Stationery	32 4 1	
Books and Bookbinding	19 12 6	
		108 11 10
Office Expenses, etc.—		
Salaries and Insurance	610 7 5	
Caretaker and Insurance	66 10 4	
Postage	111 6 8	
Telephone Charges	9 14 10	
Auditing Accounts for 1925	10 10 0	
Office Furniture and Addressograph	23 10 2	
Furniture and Repairs	23 19 6	
Petty Expenses	21 17 1	
		877 16 0
Coals, Lighting, Insurance, etc.—		
Coal and Coke	30 0 4	
Lighting	10 7 9	
Water Rate	6 0 0	
Insurance	12 19 3	
		59 7 4
Miscellaneous Expenditure.—		
Howard Prize	2 2 0	
Repair of Standard Barometer	5 12 6	
Purchase of Thermometer	0 15 9	
Portraits of Past Presidents	17 16 11	
		26 7 2
Meetings—		
Meeting Expenses, Refreshments, etc.		6 9 8
Balance—		
Cash at Bank of England	306 18 1	
Cash on Deposit at Westminster Bank	200 0 0	
		506 18 1
		£2032 7 10

Examined, compared with vouchers, and found correct.

BALL, BAKER, ASH & CO.,
Chartered Accountants.

FINSBURY COURT, FINSBURY PAVEMENT,
LONDON, E.C.2.
***January 13th*, 1927.**

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APPENDIX

ASSETS AND LIABILITIES,

LIABILITIES.

	£ s. d.	£ s. d.
Subscriptions paid in advance	48 2 0	
Electric Light	2 11 3	
Quarterly Journal, No. 220	106 18 10	
Monthly Weather Reports, 1926, estimated at	21 0 0	
		178 12 1

6% DEBENTURES.

Authorised.—160 Debentures of £50 each charged on all the property of the Society, both present and future ...	£8000 0 0	
Issued.—As at 31st December, 1925, 66 Debentures	3300 0 0	
Less.—Six Debentures redeemed during the year	300 0 0	
		3000 0 0
Excess of Assets over Liabilities*		3983 17 4
		£7162 9 5

* This excess is exclusive of the value of the Library and Stock of Publications.

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I.—continued.

DECEMBER 31, 1926.

ASSETS.

	£ s. d.	£ s. d.
New South Wales 4 per cent. Inscribed Stock, 1933, £649 1s. 7d. @ 90	584 3 5	
Funding Stock, 4 per cent., 1960-1990, £200 @ 85½	171 0 0	
		755 3 5
Subscriptions unpaid, amounting to £267, estimated at	60 0 0	
Entrance Fees unpaid	8 8 0	
Interest due on Stock, estimated at	14 0 0	
		82 8 0
Furniture, Fittings, etc.	387 11 8	
Instruments	55 8 3	
Estimated value of Society's house, 49, Cromwell Road ...	5375 0 0	
		5817 19 11
Cash at Bank of England	306 18 1	
Cash on Deposit at Westminster Bank	200 0 0	
		506 18 1
		£7162 9 5

Note.— The above Stocks are valued at prices estimated by the Society's Broker.

Examined, and Securities seen.

BALL, BAKER, ASH & CO.,

Chartered Accountants.

January 13th, 1927.

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APPENDIX

BRITISH RAINFALL ORGANIZATION FUND,

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance from 1925—Cash at Bank of England	87	3	2			
Deposit at Westminster Bank	250	0	0			
				337	3	2
Rent of 62, Camden Square				60	0	0
Dividends on Investments				88	12	6
Sales of *Rainfall Atlas*				3	11	0
				£489	7	2

RESEARCH FUND,

RECEIPTS.

	£	s.	d.
Balance, January 1, 1926—Cash at Bank of England	37	6	4
Dividends and Interest	10	0	4
	£47	6	8

SYMONS MEMORIAL FUND,

RECEIPTS.

	£	s.	d.
Balance from 1925—Cash at Bank of England	36	8	11
Interest received on Investments	26	0	0
	£62	8	11

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I.—continued.

DECEMBER 31, 1926.

PAYMENTS.

	£ s. d.	£ s. d.
Payment to Observers		36 0 0
Ground Rent		6 0 0
Repairs during year		9 17 9
Sundries during year		3 5 8
Insurance		1 7 0
Administrative Expenses, transferred to Society's General Account		10 0 0
Balance—Cash at Bank of England	172 16 9	
Cash on Deposit at Westminster Bank	250 0 0	
		422 16 9
		£489 7 2

Note.—**The Society holds on account of this Fund £2,151 London and North-Eastern Railway 3 per cent. Debenture Stock, £123 5s. New South Wales 3 per cent. Inscribed Stock, £100 5 per cent. War Stock, 1929-47, £100 5 per cent. National War Bonds, 1927, £50 5 per cent. National War Bonds, 1928.**

Examined and found correct.

BALL, BAKER, ASH & CO.,

January 13th, 1927. *Chartered Accountants.*

DECEMBER 31, 1926.

PAYMENTS.

	£ s. d.	£ s. d.
Grant towards cost of a Gorczynski radiation instrument ...	17 0 0	
Postages on Atmospherics investigation	5 0 8	
		22 0 8
Balance, December 31, 1926—Cash at Bank of England ...		25 6 0
		£47 6 8

Note.—**The Society holds on account of this Fund £85 9s. 1d. Consols, and £157 15s. 11d. 5 per cent. War Stock, 1929-47.**

Examined and found correct.

BALL, BAKER, ASH & CO.,

January 13th, 1927. *Chartered Accountants.*

DECEMBER 31, 1926.

PAYMENTS.

	£ s. d.
Gold Medal, 1926	26 0 0
Symons Memorial Lecture, March 18	10 10 0
Balance—Cash at Bank of England	25 18 11
	£62 8 11

Note.—**The Society holds on account of this Fund £700 Cardiff Corporation Redeemable Stock, 3 per cent., and £100 Registered 5 per cent. National War Bonds, 1928.**

Examined and found correct.

BALL, BAKER, ASH & CO.,

January 13th, 1927. *Chartered Accountants.*

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APPENDIX II.

DONORS TO THE LIBRARY DURING THE YEAR 1926.

1. INSTITUTIONS.

Aberystwyth, Geographical Association.
Apia Observatory, Samoa.
Athens, Observatoire National.

Baden, Landeswetterwarte.
Bangkok (Siam), Meteorological Office.
Barbados, Colonial Secretary's Office.
Barcelona, Servei Meteorologic de Catalunya.
Batavia, Royal Magnetical & Meteorological Observatory.
Beira, Observatorio Meteorologico.
Berkeley, University of California.
Berlin, Deutsche Meteorologische Gesellschaft.
Berlin, Preussische Meteorologische Institut.
Berwickshire, Naturalists' Field Club.
Bombay and Alibag Government Observatories.
Bourges, Observatoire.
Bremen, Landeswetterwarte.
Brussels, Académie Royale de Belgique.
Brussels, Ministère des Colonies.
Brussels, Société Belge d'Astronomie.
Brighton and Hove Natural History Society.
Brisbane, Royal Geographical Society of Australasia.
Bucharest, Institutul Meteorologic Central al Romaniei.
Bucharest, Observatoire Astronomique et Météorologique.
Budapest, Hungarian Meteorological Society.
Buenos Aires and Cordoba, Oficina Meteorologica Argentina.
Buenos Aires, Sociedad cientifica Argentina.
Cairo, Physical Service.
Cairo Scientific Society.
Calcutta, Indian Association for Cultivation of Science.
Calcutta, Indian Tea Association.
Calcutta and Simla, Indian Meteorological Department.
Cambridge, Mass., Harvard College Observatory.
Cambridge Philosophical Society.
Cambridge Solar Physics Observatory.
Cape Town, Royal Society of South Africa.
Cashel, Irish Rainfall Association.
Christ's Hospital, West Horsham, Natural History Society.
Coimbra, Observatorio Meteorologico e Magnetico.
Colombo Observatory.
Copenhagen, Dansk Meteorologisk Institut.
Cordoba, Academia Nacional de Ciencias.
Coventry, City Medical Department.
Croydon Natural History and Scientific Society.
Cyprus, Office of Public Works.
Davos, Meteorologische Station.
Dresden, Sächsische Landeswetterwarte.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Eastbourne, City Medical Department.
Easton, Pa., American Meteorological Society.
Edinburgh, General Register Office.
Edinburgh, Royal Observatory.
Edinburgh, Royal Scottish Geographical Society.
Edinburgh, Royal Society.
Elisabethville, Vice-Gouvernement Général de Katanga.
Falmouth Observatory.
Falmouth, Royal Cornwall Polytechnic Society.
Felstead School Scientific Society.
Geneva, Société de Géographie.
Genoa, R. Istituto Idrografico.
Glasgow, Royal Philosophical Society.
Göteborg, Svenska Hydrografisk-Biologiska Kommissionen.
Greenwich, Royal Observatory.
Grenada, Colonial Secretary's Office.
Guernsey, States Meteorological Station.
Halle, K. D., Akademie der Naturforscher.
Hamburg, Deutsche Seewarte.
Hankow, Griffith John College.
Harpenden, Rothamsted Experimental Station.
Havana, Secretaria de Agricultura, Commercio y Trabajo.
Helsingfors, Hydrografiska Byran.
Helsingfors, Merentutkimuslaitos.
Helsingfors, Meteorologische Zentralanstalt des Finnischen Staates.
Helsingfors, Societas Scientiarum Fennica.
Hongkong, Royal Observatory.
Honolulu, Bernice P. Bishop Museum.
Jamaica, Government Meteorologist.
Kiev, Service Météorologique de l'Oukraine.
Kôbe, Imperial Marine Observatory.
Leicester Literary and Philosophical Society.
Leipzig, Geophysikalische Institut.
Lemberg, Observatorium der technischen Hochschule.
Leningrad, Central Geophysical Observatory.
Leningrad, Hydrological Institute.
Leningrad, Russian Geographical Society.

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Lindenberg, Preussische Aeronautische Observatorium.
Lisbon, Observatorio Central Meteorologico.
Lisbon, Sociedad de Geographia.
Liverpool, Engineering Society.
Liverpool, Literary and Philosophical Society.
London, Air Ministry, Meteorological Office.
London, General Register Office.
London, Geological Society.
London, Institution of Aëronautical Engineers.
London, Institution of Electrical Engineers.
London, Institution of Sanitary Engineers.
London, Institution of Water Engineers.
London, International Society of Medical Hydrology.
London, Ministry of Agriculture.
London, Physical Society.
London, Royal Aëronautical Society.
London, Royal Agricultural Society.
London, Royal Astronomical Society.
London, Royal Botanic Society.
London, Royal Geographical Society.
London, Royal Institution of Great Britain.
London, Royal Sanitary Institute.
London, Royal Society.
London, Royal Society of Arts.
London, Royal Statistical Society.
Lourenzo Marques, Observatorio Campos Rodrigues.
Lourenzo Marques, Serviços de Marinha.
Lwow, Institute Géophysique de la Météorologie.

Madagascar, Observatoire de Tananarive.
Madrid, Instituto Geografico y Estadistico.
Madrid, Real Sociedad Geografica.
Manchester, Literary and Philosophical Society.
Manila, Weather Bureau.
Marlborough College Natural History Society.
Marseille, Com. Météor. Départe. des Bouches-du-Rhône.
Mauritius, Royal Alfred Observatory.
Melbourne, Commonwealth Weather Bureau.
Melbourne, Council for Scientific and Industrial Research.
Mexico, Secretaria de Agricultura y Fomento.
Mexico, Servicio Meteorologico Mexicano.
Mexico, Sociedad Cientifica "Antonio Alzate."
Michigan, University of Michigan Studies.
Middlesbrough, Albert Park Observatory.
Milan, R. Osservatorio Astronomico de Brera.
Montcalieri, Osservatorio del Real Collegio Carlo Alberto.
Moscow, Observatoire Aérologique et Géophysique à Koutshino.
Munich, Bayerische Landeswetterwarte.
Nairobi, Kenya, Dept. of Agriculture.
Newport, Isle of Wight Natural History Society.
New York, American Geographical Society.
New York, Central Park Observatory.
Nottingham City Council.

Oslo, Geophysical Commission.
Oslo, Norsk Meteorologisk Institut.
Ottawa, Dominion Observatory.
Ottawa, Royal Society of Canada.
Ottawa, Seismological Society of America.
Oxford, Radcliffe Observatory.

Padua, Reale Accademia.
Pahang, F. M. S. Administration.
Panama, Isthmian Canal Commission.
Paris, International Research Council.
Paris, Office National Météorologique de France.
Paris, Service Météorologique de la Ville de Paris.
Paris, Service Technique d'Hygiène.
Paris, Société de Géographie.
Paris, Société d'Océanographie.
Perth, Western Australia, Government Statistician's Office.
Philadelphia, American Climatological and Clinical Association.
Philadelphia, American Philosophical Society.
Phu-Lien, Observatoire Central.
Port-au-Prince, Observatoire Météorologique du Séminaire College St. Martial.
Port Moresby, Papua, Government Secretary's Office.
Porto Alegre, Instituto Astronomico e
Portsmouth Medical Department. Meteorologico.
Prague, Institut Central Météorologique de la République Czecho-Slovakia.
Prague, Institut für Kosmische Physik.
Prague, Observatoire Astronomique.
Pretoria, Department Irrigation.

Reykjavik, Vedurstofan.
Rhodesia, Southern, Agricultural Dept.
Rio de Janeiro, Directoria de Meteorologia.
Rio de Janeiro Ministerio da Agricultura, Industria e Commercio.
Rome, International Institute of Agriculture.
Rome, Ministero Aeronautica, Ufficio Presagi.
Rome, Ministero dei Lavori Pubblici.
Rome, Reale Società Geografica Italiana.

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Rome, Società Sismologica Italiana.
Rome, R. Ufficio Centrale di Meteorologia e Geofisica.
Rome, R. Ufficio Centrale di Meteorologia e Geodinamica.
San Juan, Porto Rico, West Indian and Caribbean Service.
Santiago de Chile, Observatorio de "El Salto."
Southport, Fernley Observatory.
St. Lucia, Government Office.
St. Lucia, Castries Botanical Station.
Stockholm, Abisko Naturvetenskapliga Station.
Stockholm, Hydrografiska Byrån.
Stockholm, Küngl, Sjökarteverket Skeppsholmen.
Stockholm, Statens Meteorologisk-Hydrografiska Anstalt.
Stonyhurst College Observatory.
Strasbourg, Institut de Physique du Globe.
Subiaco, Observatorio di Montecassino.
Sucre, Bolivia, Observatorio de la Companiade de Jesus.
Suva, Fiji, Harbour Master's Office.
Sydney, N.S.W., Royal Society.
Tatento, Japan, Aerological Observatory.
Teddington, National Physical Laboratory.
Tokyo, Central Meteorological Observatory.
Tokyo, Imperial Earthquake Investigation Commission.
Tokyo, Imperial University.
Tokyo, Meteorological Society of Japan.
Tokyo, National Research Council of Japan.
Toronto, Meteorological Office.
Toronto Observatory.
Torquay, Borough Observatory.
Tortosa, Observatorio del Ebro.
Tripoli, Sezione Meteorologica.
Tsingtao Observatoire.
Turin, Società Meteorologica Italiana.
Upsala, Observatoire Météorologique de l'Université.
Utrecht, K. Nederlandsch Meteorologisch Instituut.
Venice, Commissione International del Mediterraneo.
Venice, Ufficio Idrografico R. Magistrato delle Acque.
Veronesh University.
Vienna, Zentralanstalt für Meteorologie und Geodynamik.
Warsaw, Meteorological Institute.
Warsaw, Societas Botanicorum Poloniæ.
Washington, Carnegie Institution.
Washington, Hydrographic Office.
Washington, National Academy of Sciences.
Washington, Smithsonian Institution.
Washington, U.S. Coast and Geodetic Survey.
Washington, Weather Bureau.
Wellington, N.Z., Census and Statistics Office.
Wellington, N.Z., New Zealand Lands and Surveys.
Yorkshire Philosophical Society.
Zi-Ka-Wei, Observatoire Magnetique, Météorologique et Sismologique.
Zinsen, Meteorological Observatory Tyôsen.
Zomba, Meteorological Department.
Zürich, Schweizerische Meteorologische Zentral-Anstalt.

2. Individuals, Publishers, etc.

Dinsmore Alter.
R. W. Ascroft.
Baillière, Tindall & Cox.
J. Baxendell.
Ernest Benn, Ltd.
MM. Berger-Levrault.
Louis Besson.
Gebrüder Borntraeger.
S. Morris Bower.
Rev. A. H. Boys (*the late*)
Messrs. F. A. Brockhaus.
C. E. P. Brooks.
C. F. Brooks.
Cambridge University Press.
C. J. P. Cave.
Dr. C. Chree.
J. E. Clark.
Vaughan Cornish.
Crosby, Lockwood & Son.
Franz Deuticke.
S. Dezydery.
J. Dover.
Prof. F. Eredia.
Prof. Dr. J. Estetella.
Dr. H. Ficker.
R. A. Fisher.
Dr. S. Fujiwhara.
Dr. G. Hellmann.
Ulrico Hoelpi.
N. Holden.
C. P. Hooker.
D. W. Horner.
G. Hoxmark.
H. Hubert.
J. Hunter.
Dr. E. Kidson.
Prof. Dr. W. Köppen.
E. Krieg & Sohn.
W. N. McClean.
Marconi's Wireless Telegraph Co.
Miss C. Marshall.
Dr. W. E. Masters.
H. Mellish (*the late*).
E. W. Montagu Murphy.
O. Myrbach.
Negretti & Zambra.
Oxford University Press.
A. Peppler.
W. H. Pickering.
A. Preston.
Quelle u. Meyer.
P. Rintoul.
Rochester, N.Y., Taylor Instrument Co.
C. Root.
R. W. Sayles.
W. Schmidt.
E. Schweizerbart'sche Verlagsbuchhandlung.
Sir Napier Shaw.
Ernesto Sifontes.
C. Störmer.
K. Stoye.
Sydney Government Printer.
Prof. R. DeC. Ward.
R. A. Watson Watt.
Dr. C. Werth.
The Editors of—
Nature.
Observatory.

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PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 19, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society :—

JAMES COLLETT BEECHEY, St. Ives, Manor Road, Guildford, Surrey;
MILES WILLIAM BINNS, Market Street, Lutterworth, Rugby;
Rev. HAROLD BUCKTON, Fornham St. Martin, Bury St. Edmunds;
Col. WALTER JAMES GAITSKELL, Oaklands, 3, Nelson Road, Southsea;
Major GEORGE HERBERT GARRATT, Glenalvon, Aberconway Road, Prestatyn, N. Wales;
FERDINAND HUDLESTON, J.P., Hutton John, Penrith, Cumberland;
CHARLES ERNEST JACKLIN, 48, King's Bench Street, Hull;
Mrs. EDMUND JERVOISE, Newton Valence Place, Alton, Hants;
Capt. JOHN HERBERT JONES, O.B.E., R.N., Brockworth, Gloucestershire;
JOHN HAROLD NICHOLAS, 80, Hillside, Moulscombe, Brighton;
HERBERT KYNASTON GORDON ROGERS, Seaforde, Mary-Tavy, Devon;
Dr. KATSUYOSHI SHIRATORI, Taiwan Imperial University, Taihoku, Japan;
HAROLD STANIFORTH, Mount Pleasant, Thurlstone, Sheffield;
Capt. THOMAS ALFRED OWEN THOMPSON, 10, Queen's Gardens, Lancaster Gate, W.2;
ARNOLD BIRKBECK TINN, 107, Burford Road, Nottingham;
ARTHUR HENRY TURNER, A.I.A.S., Talland Lodge, Munford, Norfolk;
Rev. ROBERT WILMOT WHISTON, M.A., Orwell Lodge, Gt. Shelford, Cambridge; and
LESLIE SAMUEL FORDER WOODHEAD, The Gables, Barcombe, Lewes.

February 16, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society :—

Rev. ARTHUR JAMES DEXTER, Falstone Rectory, Northumberland;
Rev. ROBERT DOUPE, M.A., Cong Rectory, Co. Mayo, Ireland;
GEORGE HOWARD, Sitwell Vale, Moorgate, Rotherham, Yorks;
KENNETH IRONSIDE JOHNSTONE, 7, Hamilton Place, Leeds;
Lieut.-Com. GERALD MAXWELL BRADSHAW LANGLEY, R.N., 11, Belgrave Road, S.W.1;
Lady MURRAY OF ELIBANK, Ardmaddy, Oban, Scotland;
AUSTEN HAROLD NAGLE, 76, Pendle Road, Streatham, S.W.16;
JOHN EDWARD ORD, 127, Haslingden Old Road, Rawtenstall, Rossendale, Lancs;
HENRY JOHN PHILPOT, B.A., Sherfield-English, near Romsey, Hants;
Ft.-Lieut. LEO JAMES RIORDAN, 225, Elgin Avenue, W.9;
Sir GEORGE SHEDDEN, Spring Hill, East Cowes, Isle of Wight; and
Miss GERTRUDE JANE WOODD, Woodside, 7, Arundel Road, Eastbourne.

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January 19, 1927.

Annual General Meeting.

Sir GILBERT T. WALKER, C.S.I., F.R.S., President, in the chair.

Mr. R. M. LESTER and Mr. H. T. ROLLER were appointed scrutineers of the ballot for the Council.

The Report of the Council, which had been circulated to the Fellows of the Society present, having been taken as read, its adoption was briefly proposed by the President and seconded by the Secretary. The meeting resolved "That the Report of the Council be received and adopted, and that it be printed in the *Quarterly Journal.*"

It was proposed by Mr. R. H. HOOKER, seconded by Mr. P. H. HEPBURN and resolved "That the thanks of the Society be given to the Council for their services during the past year."

The PRESIDENT (Sir Gilbert Walker) expressed the thanks of the Council to the meeting for its vote of thanks. He drew attention to the amount of work which falls on the Secretaries and considered that the gratitude of the Society was especially due to Mr. R. Corless, whose health had led to difficulty in discharging his duties and who had on that account been allowed by the Council to terminate his work for them before he had served the full period. The Society was much indebted to Dr. C. E. P. Brooks for taking his place, and to Mr. Francis Druce, whose efficiency as Treasurer and zeal for meteorology was the more to be appreciated in that, unlike most of the officers, he was not professionally attached to the subject.

The President emphasized the value of the team-spirit which prevailed in the Council when he took charge from Mr. Cave; and drew attention to the indication of advancement in the position of meteorology in the Empire during the past year, citing the distinctions conferred by Government on Colonel Sir Henry Lyons and Dr. Simpson, by the Royal Society on Dr. Richardson, and by the London University on Dr. Brooks. He pointed out the significance of the initiation of the air service to Karachi in that it would bring home to the Governments of India and the Dominions the financial value of a regular service of upper air observations; he also congratulated Sir Napier Shaw on his production during the year of Part I. of his *Manual of Meteorology*.

The Buchan Prize, 1927, awarded to Mr. C. K. M. DOUGLAS, was presented to him by the President, after he had referred to Mr. Douglas's researches in meteorological science (see p. 167).

The President then delivered an Address on "The Atlantic Ocean" (see p. 97).

After the Address it was proposed by Dr. G. C. SIMPSON, F.R.S., seconded by Prof. S. CHAPMAN, F.R.S., and resolved "That the thanks of the Society be given to Sir Gilbert Walker for his services as President and for his Address, and that he be asked that the Address might be printed in the *Quarterly Journal.*" The President briefly responded.

The SCRUTINEERS then declared the following to be the Council for the ensuing year:—

PRESIDENT.

Sir GILBERT WALKER, C.S.I., F.R.S.

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VICE-PRESIDENTS.
CHARLES JOHN PHILIP CAVE, M.A., J.P.
Colonel Sir HENRY GEORGE LYONS, D.Sc., F.R.S.
Professor SYDNEY CHAPMAN, D.Sc., F.R.S.
RICHARD CORLESS, O.B.E., M.A.

TREASURER.
FRANCIS DRUCE, M.A., F.L.S.

SECRETARIES.
CHARLES ERNEST PELHAM BROOKS, D.Sc., F.R.A.I.
Commander L. G. GARBETT, R.N., F.R.G.S.
Colonel A. J. H. MACLEAN OF ARDGOUR.

FOREIGN SECRETARY.
R. G. K. LEMPFERT, C.B.E., M.A., F.Inst.P.

COUNCILLORS.
ROWLAND ARNISON, F.R.G.S.
Miss E. ELAINE AUSTIN.
Wing-Commander H. LE MARCHANT BROCK, D.S.O., R.A.F.
DAVID BRUNT, M.A., B.Sc., F.R.A.S.
LEWEN HENRY GEORGE DINES, M.A.
MAURICE ALFRED GIBLETT, M.Sc.
Sir RICHARD GREGORY, D.Sc., F.R.A.S.
HAROLD JEFFREYS, D.Sc., F.R.S.
IVAN DONALD MARGARY, M.A.
RICHARD MARSHALL, F.R.A.S.
GILBERT THOMSON, M.A., F.R.S.E.
ROBERT ALEXANDER WATSON WATT, B.Sc., F.Inst.P.

BUCHAN MEMORIAL PRIZE, 1927.

The presentation of the Buchan Memorial Prize was made to Captain C. K. M. DOUGLAS, B.A., at the Annual General Meeting of the Society on January 19.

In presenting the Prize, the PRESIDENT (Sir Gilbert Walker) said: I have much pleasure in announcing that the Council have awarded the Buchan Prize to Captain C. K. M. Douglas.

I may remind Fellows that this prize was instituted in 1923 to commemorate the merging of the Scottish Meteorological Society with the Royal Meteorological Society and in memory of Alexander Buchan, Scotland's pioneer meteorologist. It consists of a cheque for fifteen guineas with a certificate; and it is awarded biennially to the author of those papers printed in the last four volumes of our *Quarterly Journal*, or in the *Memoirs*, which are adjudged as containing the most important original contributions to science.

The first award of the prize was made two years ago to Mr. W. H. Dines, and it is gratifying that to-day the recipient of the prize is a native of Buchan's country. The members of this Society, especially the Englishmen, must always acknowledge the generosity with which the funds of the Scottish Society were placed at our disposal.

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Captain Douglas joined the army at the outbreak of the war and was soon gazetted in the Royal Flying Corps. He became keenly interested in weather and an expert cloud photographer; and beautiful examples of his work are to be found in the Scottish *Journal* as well as in our own; some effective transparencies can also be seen in the new Science Museum. The attention of the weather section of the army was thus directed to him and he was employed on observational flights for them, thus enjoying unusual facilities for acquiring knowledge of upper air conditions. After the war Captain Douglas joined the professional staff of the Meteorological Office and is now Assistant Superintendent in the forecast division: his work for which the prize is awarded has the vitally important aim of utilizing the data of the upper air for the interpretation of weather conditions down below.

Captain DOUGLAS in reply said: I should like to express my thanks to the Society for the honour which they have conferred by awarding me this prize. It is especially gratifying to me as I was for some years a member of the Scottish Meteorological Society. I am also a native of the town in which Dr. Buchan spent most of his working life, and have been acquainted with some of his works since childhood. All that I lay claim to is a real enthusiasm for the science to which Dr. Buchan devoted his life. I feel that the ground covered by the papers which you have honoured appears small when one considers the magnitude and complexity of the problems in front of us. Most of us are conscious of limited time and opportunity for research work, and at least some of us feel the lack of the higher mathematical faculties required for a further advance in the problem of understanding the weather. So long, however, as every generation of meteorologists contributes something the advance will continue, and it does not seem unduly optimistic to hope that when the Society makes its one-hundredth award of this prize, our successors will have achieved to a considerable degree the understanding of these difficult problems.

CORRESPONDENCE AND NOTES.

Henry Mellish Memorial.

In order to perpetuate the memory of the late Colonel Mellish and in commemoration of his great services to the County of Nottingham and to Education, the representative committee appointed to deal with the matter has decided to establish a scholarship tenable at a University or at the University College, Nottingham, and open to both boys and girls resident in the county or city. It is further considered appropriate that a Plaque should be placed in the Shire Hall.

The scheme will necessitate a fund of approximately £5,000, of which nearly £500 were promised at the meeting held on March 8, when the Appeal for funds was issued.

Subscriptions may be sent to:—

The Treasurer (Mr. C. O. Mosey),
National Provincial Bank,
Exchange Walk, Nottingham; or to:—
The Secretary (Mr. K. Tweedale Meaby),
Clerk of the Peace,
Shire Hall, Nottingham.

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The Weather and its Ways. III.

Atmospherics and the Atmosphere. Broadcast Talk No. 3, by R. A. Watson Watt, B.Sc., F.Inst.P., F.R.Met.Soc.

It falls to me in this third talk on "The Weather and its Ways" to tell you something of the youngest of all the branches of the great weather family. Most branches of the family, such as the cosmopolitan winds, blowing in from all quarters of the globe, the highland snows, and the melancholy but usually philanthropic rains, date from before the Flood, so to speak. But in contrast to this prehistoric lineage, the history of the upstart line of which I speak began only thirty years ago, and the recognition of its relationships is, in great measure, still more recent.

The eye of a visitor to the Shetland Isles on the twelfth of July, 1924, might have lighted, in the sombre moorlands above Lerwick, on a wooden hut of an unusual shape. If he had nothing better to do, he might have stopped to listen to the steady tick of a heavy clock, and between the ticks he might have heard the scrape of pen on paper. And on the brow of a little hill in the heart of Aldershot Camp—a hill that no longer exists—similar phenomena might have been observed. The huts had no human tenant, but the silver pens of the instruments which they housed, that very day beginning their simultaneous recording, were writing a battle story of some interest.

The story was that of the progress of a flood of cold air which was spreading steadily in from the Atlantic over western Europe, cutting under the warm air which then lay over the continent.

At 2 p.m. the battle front between this invader from the polar regions and the retreating defender was just west of the Outer Hebrides. The news from the front, which was being transcribed at Lerwick and Aldershot, took the form of crashes in a wireless receiver, crashes not unfamiliar to my present audience. They were the product of the electrical turmoil involved in the conflict of the rival air currents, and the two instruments were recording the directions along which atmospherics, as these crashes are called, were reaching them. When the directions were laid off on a suitable map they met at the one point on the front which was, for the time, the centre of battle. As the long summer day drew on, the directions swung inward, that at Lerwick from south-westerly towards south, that at Aldershot from north-westerly towards north, showing how the invader was over-running Scotland from the west. The severity of the struggle was marked, towards mid-afternoon, by a violent thunderstorm at Renfrew. By 6 p.m. the cold air had reached Ross-shire; by 9 p.m. it was at the mouth of the Firth of Forth, these places being indicated by the recorders as the main places of origin of atmospherics at these hours.

But then a curious thing happened. The recorders ceased to give indications of one well-marked source of disturbance, and throughout the hours of darkness this failure persisted. It is fairly certain that the reason was that the production of atmospherics over the sea in darkness was less vigorous than over the land in daylight, and that the stream of disturbances which reaches us every night from other places overlaid this weakening supply from the North Sea.

At 5 a.m. on the 13th, however, the recorders showed that the atmospherics were coming from a place off the Norwegian coast, whither the cold air was now approaching. Hour by hour through this second

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day the advance of the cold air could be traced by plotting the directions from which atmospherics arrived, from Stavanger at 1 p.m., from Mecklenburg-Strelitz at 6 p.m., from Posen at 10 p.m., until at length, in the early morning of the third day, the battle front reached the Roumanian coast of the Black Sea, and the directions of arrival of atmospherics at Aldershot and Lerwick from a source so distant differed so little that we could no longer make use of them.

I take this episode in the life of an atmospheric recording system in such detail because it gives a very clear justification of the introduction of atmospherics as members of the weather family, and because the difficulty when other supplies of atmospherics mixed themselves up with North Sea atmospherics is typical of the difficulties of research on such disturbances.

When, thirty years ago, men began to use wireless waves for the carrying of messages they were perturbed by finding their instruments responding to stray impulses which certainly did not come from the few artificial transmitters then existing. Clearly, impulses of this random kind had been straying through space during uncounted ages, but it was only when the wireless ear was added to our senses that they took their place in the world of things known.

The telephone receiver translated them into a variety of crackling, crashing, hissing, sizzling, rolling, grinding noises, and in recognition of their wandering nature and their unknown origin these disturbing impulses were called "strays" or "Xs." After a few years some rash fellow called them "atmospherics," and not all the twenty years that have since elapsed have sufficed to prove up to the hilt that all atmospherics originate in the atmosphere. I believe that they do, but it is not finally proved. The example I have given you will, nevertheless, convince you of the eternal wisdom of Mr. Punch, who recently put the title "Atmospherics" over the inquiry "Tell me, Joan, is that a saxophone or a deep depression over Iceland?" Beyond saying that both are wind instruments, I must leave the relation between atmospherics and saxophones to the music critic, but the deep depression contains the battle front I have described, and the atmospheric is the signal from the front.

So, too, you will realize, as Mr. Maurice Lane Norcott in a Christmas Number of the *Radio Times* meant you to realize, how very ignorant were people in the days when they hardly knew an atmospheric from an anticyclone. For an anticyclone is an armistice, and I believe that X signalling is usually suspended in anticyclones.

In the first days of November, 1924, the pair of recording stations which I have mentioned was supplemented by the installation of identical recorders in Egypt and India, the four instruments being provided by the Department of Scientific and Industrial Research on the advice of its Radio Research Board. On November 7 the English, Scottish and Egyptian instruments recorded throughout a whole day the southward progress of a mass of cold air flowing over the Mediterranean, and recognizable on the weather map as the cause of a trough of low pressure near Sardinia.

On October 9, 1925, all four recorders agreed in locating, as the source of the main atmospheric stream reaching them, a region almost identical with that of November 7, 1924, and again the weather map revealed a well-marked front with cold air driving southward, lifting warm air in its path and producing a trough of low pressure off the Italian coast.

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At 1.30 p.m. on a summer day in 1917 six British direction-finding stations from Peterhead to Cork found time in the midst of their war duties to report that atmospherics were reaching them from certain well-marked directions, which were all found to pass through the town of Helmond, near the eastern frontier of Holland. We learned afterwards that a thunderstorm had begun at Helmond at 1.5 p.m. and ended at 2 p.m. on that day.

Thus there are many occasions on which a single thunderstorm supplies the principal atmospherics heard over the whole of Great Britain, many occasions when a single low pressure trough dominates the supply of atmospherics to places so far apart as Great Britain and Egypt, and some cases at least in which one such trough provides the main stream of atmospherics heard in places so widely spaced as the Shetland Isles, the Mediterranean coast of Egypt, and the hill country of Southern India.

In ninety per cent. of the hundreds of individual places of origin of atmospherics which I have examined, the source lay either on the trough of a depression or at a place where rainy or squally conditions prevailed.

That some atmospherics come from ordinary thunderstorms has been known from the earliest days of radiotelegraphy, but the two apparently simple questions "At what distance from a thunderstorm will an ordinary receiver hear the atmospherics produced by the storm?" and "Are there enough thunderstorms in the world to account for all the atmospherics heard?" are not yet conclusively answered. The examples I have quoted show atmospherics being written down by a comparatively insensitive receiver 1,600 miles from the source, and we have many well-authenticated cases of such ranges, but much remains to be done before we know all that is to be read from the message of the X.

Another method of observation, of which the idea was copied from Australia, is telling us something more detailed about these ranges of reception of atmospherics. On July 9 of this year, for example, an unsuspecting speaker was seated, as I am now, talking quietly to this microphone. He was happily unaware that by a benevolent conspiracy between the British Broadcasting Company and the Royal Meteorological Society every word he said was being used as a time signal by a small corps of atmospheric observers throughout the country. These observers, as they listened to his talk, marked on the copies of the manuscript which they held every word which was mutilated by an atmospheric. We were thus able to find with practical certainty whether any particular atmospheric was heard at two or more stations. The evening in question was a very disturbed one, a trough of low pressure lay over the British Isles, and we have seen that such conditions favour the production of atmospherics. In the course of a quarter-hour talk fourteen observers reported 282 distinct atmospherics. Of this number, 237 were heard at two or more stations, 74 at six or more, fourteen at ten or more, and one atmospheric was heard at all fourteen stations. In one special case six observers agreed with definiteness on the particular syllable on which one atmospheric began; amongst these were an observer in Darlington listening to London and one in Falmouth listening to Daventry. Thus on two wave-lengths the same atmospheric was heard over the whole length of England.

It is hoped to continue and extend these observations in the present autumn season, and they promise to yield very interesting information on the habits of atmospherics.

I do not wish to trespass on the ground to be covered by Dr. Simpson

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next week, but I want to say that all the evidence we possess goes to show that a lightning flash is a fine high-power wireless transmitter, with an aerial some miles high, dissipating a million horse-power, having a wave-length of about a million metres, full of what I may for brevity be allowed to call "harmonics," and with such a broadcast range that it is capable of sending its signals, atmospherics to wit, once at least round the world. Whether these super-Daventrys are the only broadcast stations of the kind is still not clear, but it seems reasonable to believe that there are probably super-2LO's and low-power X transmitters in the shape of smaller discharges of the same essential nature as the big lightning flash.

I have shown you that we have persuaded Mr. X to sign the visitors' book, I cannot stop to tell you how, more recently, we have contrived that he should sit for his portrait. It is, however, almost inevitable that when I say "atmospherics" someone else should say "elimination," because very few people share my affection for atmospherics.

Now the terms "atmospheric elimination" and "atmospheric eliminator" are rather unhappy ones. The history of civilization is largely the history of man's efforts to minimize the inconvenience produced by the weather and its ways, and civilization took a step forward with the introduction of the umbrella. But no one calls an umbrella a "rain eliminator." Atmospherics are the rain of the radiotelegraphist, and as we cannot go out and clap an extinguisher on the source of atmospherics we can only hope to devise what I may call X-umbrellas to let as little atmospheric disturbance as possible leak through to the output of our receivers. It is hardly a question of elimination but of minimization. And, as I am this evening talking as a meteorologist and not as a radiotelegraphist, "that is a different story."

Many hard things have been said, and said with reason, about atmospherics. But, speaking still as a meteorologist, I must urge that the atmospheric is a valuable ally in increasing our knowledge of the weather and its ways. The long range of reception of atmospherics from troughs of low pressure, of which I have quoted a few samples only from many, makes the preliminary study of atmospherics a hard one, for it means that we have to study the weather of half the world to find the origin of the X-signals crowding in on the receiver in the village hall. But, once the study has made progress, that long range is a promise that the message carried by the atmospheric will be of great value to the weather forecaster, and, in particular, to that most sorely tried of the meteorologists of the future, the forecaster who will be responsible for the safety of the long-distance airways of the Empire.

Thunderstorms. Broadcast Talk No. 4, by Dr. G. C. Simpson, C.B., F.R.S.

In the fifteen minutes at my disposal this evening I have to try to explain to you how the great electrical forces involved in a thunderstorm come into action. As this is a large and somewhat complicated subject I must not waste time on a general description of a thunderstorm, but will start straight away by describing the problem which has to be solved.

If you watch a thunderstorm at a distance you will see that the lightning discharges appear to start mainly from a small region of the cloud. Some of the flashes pass from this region to the earth, but a large number pass into the cloud itself and a few leave the cloud and seem to die out in much branched discharges in the clear surrounding

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air. Now those of you who know anything about electricity will realize that before a lightning discharge can take place from a cloud, that cloud must obtain a very large charge of electricity. Ever since Franklin in 1752 proved the electrical nature of lightning, many attempts have been made to explain the origin of the electricity in a thunderstorm. Some investigators said that the electrification is due to the friction between different masses of air, others that it is due to the freezing of raindrops when hail is formed, and others that it is due to the action of sunlight on ice particles high up in the atmosphere. But against all these explanations, fatal objections were raised. In 1909 I commenced an investigation of the problem, my endeavour being to reproduce in the laboratory all the natural processes which occur in a thunderstorm, and to see if any of them were accompanied by electrical effects. I caused friction between dry and damp air, between hot and cold air, between clear air and cloudy air; but I could get no electrification. I then froze drops of water attached to the most delicate electrical instruments, but could detect no electrification, either when the water changed into ice or when the ice changed into water. The next experiment to be made was to see if the breaking of raindrops was accompanied by electrification, for we know, as I shall explain later, that large raindrops are frequently broken up into small drops during a thunderstorm. To do this I arranged a piece of apparatus from which drops of water fell at a rate of about two a second, so that they could be counted as they fell. About two feet below the tube from which the drops were falling and right under it I fixed up a glass nozzle through which a strong jet of air could be directed upwards. When the jet of air was fixed in position, each drop fell on to it and was immediately split up into a number of small drops which fell into a tray set to catch them. I then tested the drops for electricity before and after they had been broken up on the air jet. There was no mistake about the result. When the drops were not broken on the jet they were entirely unelectrified; but after breaking on the jet the water which was caught in the tray was highly electrified. This was a very encouraging result, but many more experiments had to be made before I could be sure that drops of rain falling through the air could become electrified in this way. Other observers have, however, repeated the experiments, and now we know that when drops of pure water are broken up in the air they become charged with positive electricity, the corresponding negative electricity being given to the surrounding air. It is legitimate to argue from this that when raindrops are broken up, not only do they become charged with positive electricity, but the air itself becomes charged with negative electricity.

This, however, did not solve the thunderstorm problem, for we get a great deal of rain, sometimes lasting for days together, without any thunder and lightning. There must, therefore, be some other factor which will determine whether a rainstorm will or will not develop into a thunderstorm. What is this factor? To answer this question I must introduce you to quite a different aspect of a thunderstorm, for which we must now leave the question of electricity and examine why it is that rain always falls in drops, what is the size of these drops and how fast they fall.

If a drop of water, say, a raindrop, starts to fall from a great height, it falls at first slowly, but gradually gets up speed. On the other hand, the faster it falls the greater is the resistance of the air, until finally the resistance becomes so great that the drop cannot fall any faster, but

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continues for the rest of its fall to move at the same speed. Every drop after it has fallen for quite a short distance continues to fall at a constant speed which we call the "end velocity." The end velocity, then, is the fastest rate at which a drop can fall through still air. The end velocity depends on the size of the drop, the larger the drop the faster it falls; but every drop has an end velocity according to its size which it cannot exceed. It is easy to calculate the end velocity for different sizes of drops, and measurements show that the calculations are correct. If the drop is very small, so small that you can hardly see it, say, the small drops of which a cloud is formed, its end velocity is very small, only a few feet a minute. That is why clouds appear to float, because the drops of which they are formed fall so slowly that you cannot detect the motion. When, however, the cloud particles join together to make small raindrops, these fall more rapidly; for example, fine raindrops of the drizzle type fall at about three feet a second. Larger raindrops fall more rapidly until we come to drops of about a quarter of an inch in diameter, which fall at about 24 feet a second. Now here comes a most important and interesting observation, there are no raindrops with a larger diameter than a quarter of an inch. This has been proved by observation of the size of actual raindrops and by careful experiments in the laboratory. If we make a drop of water larger than this and let it fall, it almost immediately breaks up into smaller drops. From this follows the important fact that so long as a raindrop is smaller than a quarter of an inch in diameter it can fall unbroken through the air, but if it grows larger, it at once breaks up into a number of smaller drops. Do you see the important consequence of this? No raindrop can fall more rapidly than 24 feet a second, for this is the end velocity of the largest drop which can exist unbroken when falling through the air.

So far we have only considered raindrops falling through still air, but the air is not still in a thunderstorm; it often has an upward velocity and in places a very large upward velocity. What happens to a raindrop which meets an upward current of air? The current of air tries to blow the drop upwards, and if it is moving upwards more rapidly than the rate at which the drop can fall downwards, it will suceed. Let us think of a drop of the maximum size which, as I have said, falls through still air at 24 feet a second. If the drop meets a current of air moving upwards with a velocity of 24 feet a second, the drop will neither rise nor fall; it will stop just where it is. If the current of air is moving upwards faster than 24 feet a second, the drop will not fall at all, but will actually be carried upwards. If I have been able to explain this clearly, you will see that an upward velocity of 24 feet a second is a critical velocity in the atmosphere, for no rain whatever can fall through it.

Before going further, let me just sum up what I have said so far:

Firstly, a raindrop cannot be larger than a quarter of an inch in diameter.

Secondly, the largest raindrops cannot fall faster than 24 feet a second; smaller drops fall more slowly.

Thirdly, if the air is moving upwards at a greater rate than 24 feet a second, it carries all the rain up with it, and no rain can fall.

Fourthly, whenever a raindrop breaks in the air, it becomes charged with positive electricity, while the air receives the corresponding negative charge.

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Now I hope you will be able to understand the following description of the mechanism of a thunderstorm. I want you to picture a hot summer's day with the sun beating down through a clear sky. The sun warms up the ground and this heats the air lying in contact with it. But it is the tendency of warm air to rise, and during the course of the day ascending currents start here and there and rise through the surrounding atmosphere. The air of these currents as it ascends gets colder and colder, until the water vapour it contains condenses into clouds. You have all seen on a summer day heap clouds appearing in all parts of the sky. Each one of these is the top of an ascending current, and if you watch them carefully you will see that they continually get higher and higher as they develop. If the conditions are suitable, these currents and the clouds associated with them grow very rapidly, and finally we get the great masses of cumulus cloud which we all associate with a thunderstorm. Into this cloud the air is ascending at a rapid rate. You cannot see the ascending current itself, but you can sometimes see leaves and paper being blown inwards and upwards by the wind which is feeding the storm.

The ascending currents are composed of warm damp air, and therefore they carry upwards great quantities of water in the form of vapour, which is deposited first as cloud particles and then as rain. At first the rain falls through the ascending currents of air, but, as the latter increase in intensity, first all the small drops get held up and then the larger drops.

Finally there comes a time when in some part of the ascending current the velocity becomes greater than 24 feet per second. Through this part of the ascending current no water can fall; but this is just the place where the water is being deposited at the greatest rate, for the more rapid the current, the more water vapour is carried upwards. The large amount of water which is thus prevented from falling accumulates near the top of the current where the upward velocity falls off. The accumulation of water can become very great. Sometimes the ascending current suddenly stops and then the accumulated water falls and we get what is called a cloud burst.

All the time the water is being held up by the ascending current it is going through an important process. Small drops are constantly uniting to form large drops, which in turn are broken up again into small drops. In this region of the cloud, therefore, thousands and thousands of drops are broken up every second, and every time a drop breaks there is a separation of electricity, the drops becoming positively charged and the air negatively charged. But while the drops remain near the top of the ascending current the negative electricity is carried rapidly away in the air stream. This process goes on until the charge on the rain which is being held up becomes very large indeed. Finally, the electrical force becomes so great that it is discharged by a lightning flash. But this only relieves the electrical pressure for a short time; the water remains and continues to be broken up, so more charge is produced which gives rise to further lightning discharges.

I said at the beginning of my talk that usually the lightning appears to start from one portion of the cloud, and now you see the reason why; for that portion of the cloud is where the ascending current causes the water to accumulate and it is there that the separation of electricity is at its maximum and so that is the chief centre of the lightning discharges.

I have now given a very rapid but somewhat incomplete account of the mechanism of a thunderstorm. You have seen that the electricity is

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produced by the breaking up of the rain: but you have also seen that it is necessary for there to be an ascending current of more than 24 feet a second before the water can be held up in sufficient quantities to produce the large electrical field necessary for a lightning discharge. If this critical velocity is not reached, the rain simply falls to the ground without thunder and lightning being produced. Thus we see why all rainstorms are not thunderstorms, and why all thunderstorms are associated with heavy rain.

In conclusion, I must say a few words about the thunder. There are two things to explain about thunder; the first is the noise itself, and the second is the long-drawn-out rumble. There is little difficulty in explaining the noise. As the lightning breaks its way through the air extremely high temperatures are generated in the narrow channel which it cuts for itself. The light given out by a lightning flash is evidence of this high temperature, for the air becomes, in popular language, white hot. This high temperature causes the air to expand all along the path of the discharge with explosive violence. It is the explosion wave generated in this way which we hear as thunder. The rumbling is due to several causes. A lightning flash is often several miles long, and the explosion wave from the near end will obviously reach us first, then the wave arrives from more distant parts. As it takes five seconds for sound to travel a mile, it is clear that the sound from the far end of a flash two miles long will arrive ten seconds after we hear the sound from the near end. During the whole of this ten seconds, sound is arriving from different points along the flash, the intensity of the sound rising and falling according to the direction taken by the flash. Another cause for the rumbling is the echoes which reach us from mountains and even from clouds. These echoes arrive at different times and add to the noise we hear. Finally, there may be several flashes taking place so rapidly one after the other that the thunder from one flash arrives before the thunder from the previous flash has died out. Thus the thunder is caused by the explosive heating of the air in the channel of the lightning discharge, while the drawn-out rumbling is due to several causes, the chief of which is the long time it takes for sound to travel from the distant end of the lightning flash.

Direct Hit by Lightning.

We are indebted to Mr. L. W. Swainson, M.I.M.E., the district engineer of the London Midland and Scottish Railway at Crewe, for the following particulars and diagram of the path of a lightning flash at Tidenham Chase, on the property of Mr. H. S. Burder.

The storm occurred on March 18, 1926, during a period of NNW winds, when heavy squalls of snow and hail were experienced hourly. Distant thunder was heard on the 16th and 17th, but only one discharge occurred during the 48 hours March 17 to 19.

The path of the lightning is shown in the accompanying diagram. It first struck the tree near the barbed wire fence, stripping off the bark. It then jumped a gap of 17 inches to the galvanised iron fence (A), four strands of which were melted. The iron supports were left intact. Travelling along the wire it jumped (B) to the galvanised iron sheets on the end of the shed, hurling a sheet twenty yards into the fields, while furrows ending in small holes were made in the field at the rear. Passing to the front of the shed it travelled along the iron guttering

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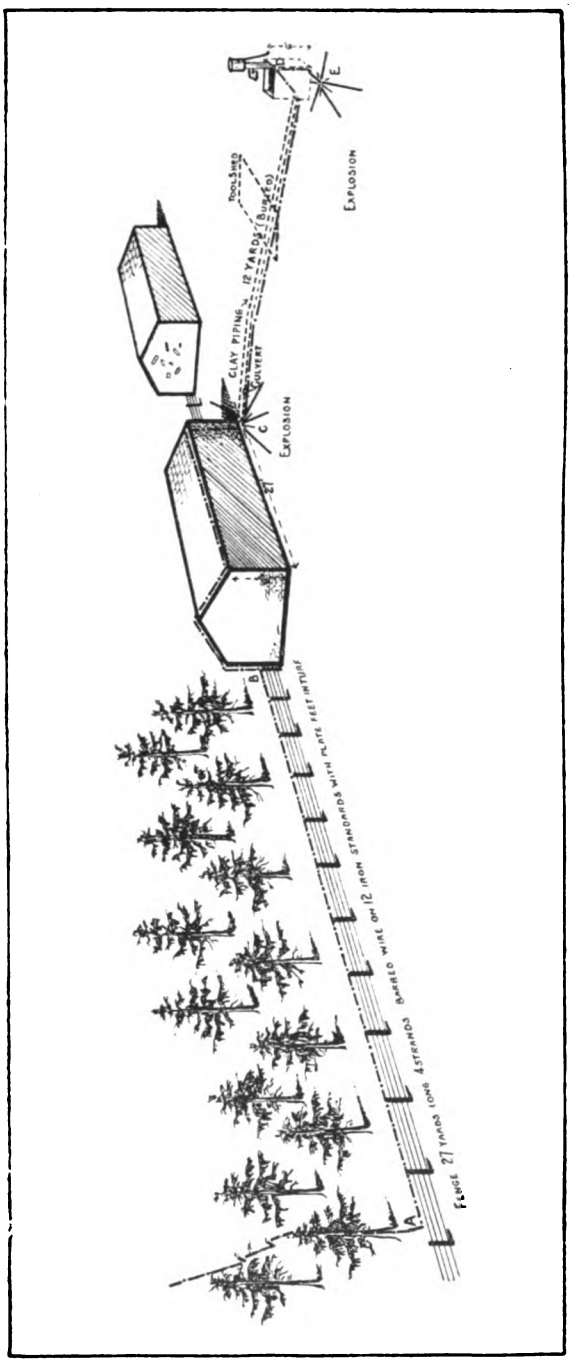

Fig. 1.—Direct hit by Lightning, Tidenham Chase.
Lightning path, — · —

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and the down spout to the stone culvert. In the culvert (C) the first of the two explosions occurred, pieces of stone being hurled against the adjoining buildings. These are indicated at the front end of the rear shed. The lightning then passed along clay piping underneath the foundations of the tool shed. The foundations consisting of large stones were heaved up. The end of the piping was broken off, the suction pipe union (D) at bottom of the pump was melted, and the top of the tank blown off. The tank was of cemented limestone buried in the ground, the base being of 3in. stone slabs with 3in. of concrete over. The second explosion which occurred at the bottom of the tank (E) made a large hole in the base. The total distance from the tree to the pump was 57 yards. The original of the diagram bears the signatures of the witnesses, Mr. H. S. Burder and Mr. L. W. Hagen.

Tropical Cyclones in the Central South Pacific during 1925-26.

In the rainy season, November 1925 to May 1926, five notable tropical cyclones occurred in the South Pacific Ocean between longitudes 170°E. and 135°W. Some details are given in Table I.

TABLE I.—Tropical Cyclones occurring in the South Pacific Ocean during 1925-26.

No.	Time.	Island Groups affected.	Destruction.
1	Dec. 16-23	Union, Samoa, Cook.	Tidal wave in Union Group, destructive winds in Rarotonga.
2	Dec. 17-20	Ellice.	Not stated.
3	Dec. 31-Jan. 1	Union, Samoa.	Three lives lost and destructive winds in Samoa.
4	Dec. 31-Jan. 1	Society.	Eleven lives lost through flood caused by excessive rain.
5	Mar. 26-Apr. 1	Union, Samoa, Cook.	One life lost, tidal wave and high winds in Cook Group.

The observations from a recently established station at Atafu, 8.5°S., 172.5°W., showed that three of the cyclones had their beginning within the belt 5°-10°S. Two were preceded by days of continuously overcast sky with light winds, and the third was preceded by squally weather with strong winds from N.E. and N.W. In each case the temperature for the three days prior to the cyclone in the locality of its formation was lower than the mean monthly temperature. An intensification took place between 10°S. and 12°S. so that at Atafu the strongest winds occurred when the eye of the storm had already passed to the south and the island was no longer in the navigator's " dangerous " semicircle.

On each occasion that cyclones developed there existed a vast low pressure area spreading east and west for at least 2,000 miles. During the cyclones of December 16-21 the lowest pressure for the month occurred simultaneously on December 19 at Fiji and the Society islands, 1,800 miles apart. On January 1 destructive cyclones affected at the same time both the Samoan and the Society islands. The only other windstorm occurring in the Society islands during the first six months of the year took place on March 29, when a cyclone was developing in the Union Group. Although the pressure records are too scanty to draw the isobars

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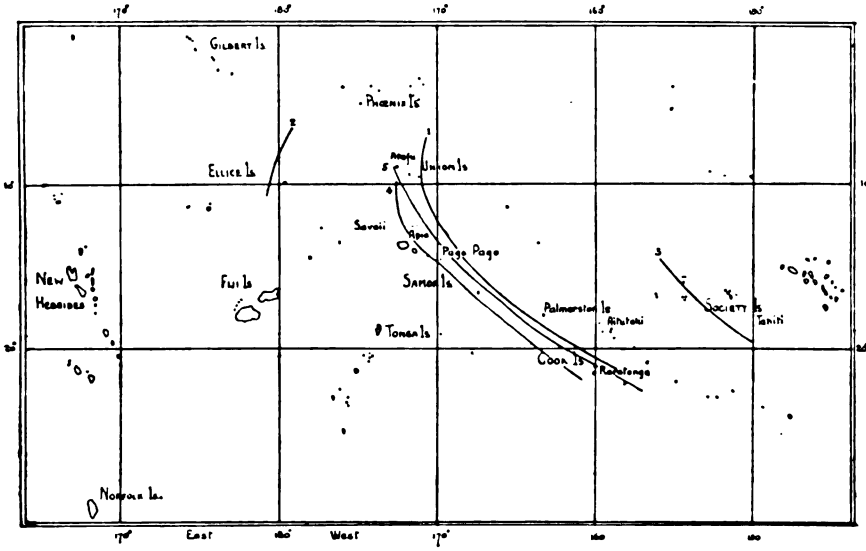
it is fairly evident that these cyclones and windstorms were entirely independent of each other.

It appears, however, more than a coincidence that the six storms took place in pairs. Probably in conjunction with the low pressure the necessary convection conditions occurred simultaneously in the widely separated localities where the cyclones developed.

The energy which the storm of December 16-21 maintained throughout 1,600 miles of its path was such that a tidal wave was caused at Atafu (Union Islands) and a destructive windstorm at Rarotonga (Cook Islands). For parts of the path the cyclone was elliptical with a short axis of 250 miles. From observers' reports it would appear that the maximum wind velocity was of the order of 75 miles per hour, but it is highly probable that the wind exceeded 100 miles per hour at one or more of the islands passed over. The lowest barometric reading recorded was at Pago Pago (Tutnila, Samoa) when, in the eye of the cyclone of December 31-January 1, the barometer fell to 28.75 inches. No reports were received of the barometer " pumping."



Tropical Cyclones occurring in the South Pacific during 1925-26.

At least three of the five cyclones produced tidal waves which were followed subsequently by huge seas. No precise information is available of the tidal wave which occurred in the Union Islands on December 19. In the Ellice Islands there was a series of three waves which followed one another rapidly. The Cook Island parliamentary report gives fairly complete details of the tidal wave in that group on March 31. " At Palmerston (Island) the wave occurred simultaneously with the onset of the first fury of the storm. The whole atoll was swept and completely devastated; and every building with the exception of the church was wrecked. A mound 20 feet high in the centre of the village barely provided a refuge for 105 inhabitants." Supposing the wave advanced S.E. along a plane front parallel to the direction of the storm, its velocity was 24 m.p.h. from Palmerston to Aitutaki Islands in mean latitude

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19°S., 17 m.p.h. from Aitutaki to Rarotonga in mean latitude 20°S. and 11 m.p.h. from Rarotonga to Mangaia in 22°S.

The factors which cause the presence or absence of thunder and lightning in a cyclone have not been learned. Thus Apia on the outskirts of the cyclone of December 18-21 experienced an electrical storm. On December 31-January 1 no thunder and lightning were observed, although the centre passed within 50 miles of Apia; and two months later, although the centre was farther off, no electrical storm took place. Better evidence of the existence of electrical disturbance in a large area is in the production of "statics." Records have been carefully kept by the local high-power wireless station. During the cyclone December 18-21 statics were so extremely bad that no messages could be sent or received, yet on December 31-January 1 when two fully developed cyclones were raging simultaneously both transmission and reception were good and statics were almost normal. In the cyclone at the end of March statics again interfered, showing that there were a few scattered electrical storms. General atmospheric conditions, such as humidity and duration of sunshine, were alike in all the storms, and no clue has been found which would explain variations in the ionization of the air or account for the great difference in the electrical energy displayed.

The storm paths, so far as is known, were fairly straight lines from N.W. to S.E., the storms moving S.E. directly opposite to the trade winds. The velocity of movement of the storm centre in the straight path from Apia to Rarotonga was approximately 300 miles per day. Two of the cyclones moved from Atafu to Apia at about 125 miles per day, but in the Samoa cyclone of January 1 the velocity of the storm centre for this part of the path was 240 miles per day.

Torrential rains invariably accompanied the cyclones, the rain occurring almost entirely in the area in front of the eye of the storm. At Apia for the cyclones of December 16 and March 31 the rainfall was 133.8 mm. and 119.8 mm., and for the cyclone of December 31-January 1, which approached nearer, the rainfall was 179.6 mm. On this date the rainfall at Papeete (Tahiti, Society Islands) amounted to 567 mm., and caused the loosening of the retaining wall of the reservoir. A highly cultivated valley was thereby flooded and eleven deaths resulted. Although the cyclones occurred in the height of the rainy season when the normal rainfall at many of the stations is 12 mm. per day, after they had passed there followed a fortnight or more of dry weather and clear blue sky. The barometer only slowly regained its normal value and did not rise above it.

The seismographs at Apia recorded microseisms of the order of 15-20 microns in the horizontal plane during the passage of each of the cyclones. The microseisms which are normally at Apia less than six microns increased slightly to eight microns on the day prior to the cyclone, but in no case was the increase sufficiently marked to give warning of the approach of the storm. The microseisms were largest when the cyclone centre was nearest but persisted with only slightly diminished size for the following two days, that is until the centre was over 600 miles distant; then there was a rapid decrease to normal size. The period of the microseisms did not exceed five seconds, which is only slightly in excess of the period normally experienced in quiet weather, and gave no clear indication of true seismic waves transmitted from a distant source. The movement in the vertical was very small, not exceeding 1.5 microns.

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Two other storms occurring outside of the rainy season should also be mentioned. One, a true tropical cyclone, reported by the officers of the French frigate *Cassiopée*, occurred on May 4-6. The diameter of this storm was very small—less than 75 miles—and the wind near the centre was of force 9. The second storm occurred on July 10 and was noteworthy for having invaded the tropics, the centre when first reported being south-east of Norfolk Island, about latitude 28°S. The centre then moved N.E. passing through the Tongan Group, latitude 18°S. Strong winds resulting from this storm were experienced within 10° of the equator. A. THOMSON.

Royal Observatory, Greenwich. Report to the Council of the Royal Meteorological Society for the year 1926. (Communicated by the Astronomer-Royal.)

Meteorological observations have been continued as in previous years. Estimates of "visibility" at 9h., 15h. and 21h., according to the international scale, are included among the observations telephoned to the Air Ministry daily in the general weather report.

During the year 1926 the temperature of the air varied between 88°.2F. on September 19 and 16°.0F. on January 16. On 13 days it rose to 80°F. or higher, and on 28 days it fell to 32°F. or lower. Maximum temperature for the year has only occurred in September on three previous occasions since records began at Greenwich.

The mean temperature for the year was 50°.5F., or 0°.9F. above the average for the 75 years 1841-1915.

February was almost the warmest February recorded, with a mean temperature of 45°.5F. This is nearly 6° above normal and has only been surpassed once (in 1869) when a mean temperature of 45°.6F. for the month was recorded.

The extreme readings of the radiation thermometers were 154°.4F. on June 21, and 12°.0F. on January 16 respectively. A range of 100°F. or more occurred on 36 days, the maximum range being 114°.3F. on June 1.

The total number of hours of bright sunshine registered during the year was 1230.7. June 30 was the day of maximum duration, the register showing 14.3 hours.

The deficiency mentioned last year continued during 1926 and was even more marked. There were 77 entirely sunless days, no month except August reaching the normal.

The proportion of clear sky at night, as given by the night-sky recorder, amounted to 39 per cent. for the year. A similar relation to the percentage of bright sunshine mentioned in last year's report appeared, showing that for the winter months the ratio of clear nights to clear days increases very considerably.

In the matter of rainfall, the year as a whole produced 3.88 inches more than the average for 75 years. The total amount collected was 28.12 inches. There were, however, two abnormally dry months, March —the driest March ever recorded—with 0.14 inches, and December, whose total of 0.38 inches surpassed only that of the dry December of 1873. November was the wettest month of the year, its total rainfall of 4.77 inches not having been rivalled in November since 1861.

Two days had rainfall of over one inch. These were August 11 (1.09 inches) and September 1 (1.53 inches).

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The total number of "rain-days" (with .005 inch or over) in the year was 178.

For the second year in succession a remarkably low barometer reading occurred, the reading of 28.39 inches on December 20, 1925, having been matched with one of 28.31 inches on November 20, 1926. The barometer readings remained below 29 inches for 86 consecutive hours during the passage of this depression as compared with 77 during the passage of the first-named.

The total horizontal movement of the air recorded by the Robinson anemometer was 101,734 miles. The greatest daily movement was 707 miles (on March 4); the least 47 miles (on November 25). The greatest hourly velocity in the year was 43 miles on October 9, which day also provided the greatest wind pressure recorded by the Osler anemometer, namely, 15.2 lbs. to the square foot.

The Aurora Borealis of March 9 was seen at the Observatory, though on account of haze towards the north, which when present is always strongly illuminated by the lights of London, little detail could be made out. A sudden and remarkably steady sweep of the declination magnet towards the east at 20h. coincided with the culmination of the display.

Meteorological Observations at the Radcliffe Observatory, Oxford, 1926. (Communicated by the Radcliffe Observer.)

The following were the chief characteristics of the weather at Oxford during the year 1926:—

The mean *Barometric Pressure* at 9h. G.M.T. (barometer reading reduced to 32°F. and mean gravity) was 29.743 inches, which is 0.011 inch below the mean for 70 years.

The mean *Maximum Temperature* of the air was 57°.3F., which is 0°.8F. above the mean for 75 years. The mean *Minimum Temperature* of the air was 43°.4, which is 1°.0F. above the mean for 75 years. The absolute maximum temperature, 85°.3F., was recorded on September 19; and the absolute minimum, 6°.3F., on January 17. The lowest grass minimum temperature, 0°.5F., occurred on January 17.

The temperature of the air reached 80°F. on 8 days and fell as low as 32°F. on 36 days. The number of days of ground frost (grass minimum as low as 30°.4F.) was 69.

The differences of the mean monthly temperatures (mean adjusted from maximum and minimum) from the corresponding means for 97 years are:—

	°F.		°F.		°F.
January ...	+1.2	May ...	−1.9	September	+2.8
February ...	+5.3	June ...	−1.4	October ...	−2.7
March ...	+2.0	July ...	+1.1	November	+0.8
April ...	+2.2	August ...	+1.3	December	−0.8

Wind.—The total movement of the air recorded by the Robinson anemograph with cups 116 feet above the ground was 74,704 miles, the records being reduced with the factor 2.2. The mean velocities of the wind for each month are given in the following table:—

	mi./hr.		mi./hr.		mi./hr.
January ...	10.70	May ...	9.09	September ...	6.80
February ...	9.01	June ...	7.43	October ...	7.57
March ...	10.14	July ...	7.81	November ...	9.79
April ...	7.53	August ...	8.27	December ...	8.14

The number of hours of *Bright Sunshine* amounted to 1,378, which is 104 hours below the mean for 45 years.

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The monthly differences from the mean are shown in the following table :—

	Hours.		Hours.		Hours.
January ...	− 5	May ...	−5.3	September ...	−2.9
February ...	−2.7	June ...	+ 5	October ...	+ 8
March ...	+ 3	July ...	− 9	November ...	−1.2
April ...	−3.0	August ...	+2.5	December ...	+2.0

Rainfall amounted to 27.379 inches, being 1.186 inches above the mean for 111 years. The number of "rain-days" (0.005 inch or more) was 187.

The monthly differences from the mean were :—

	Inches.		Inches.		Inches.
January	+2.006	May	+1.136	September	−1.078
February	+0.469	June	+0.212	October	−0.695
March	−0.998	July	+0.093	November	+2.197
April	+0.889	August	−1.287	December	−1.758

Solar halos were observed on 149 days, parhelia being present on 21 days, and on two occasions parhelia were seen with no halo. The 46° halo was seen on October 17 and (with the zenithal halo) on October 25. Contact arches were observed on 12 days. *Sun pillars* were seen on January 16, August 4 and October 16.

Lunar halos were observed on 41 nights, being accompanied by a contact arch on May 25 and October 19; contact arch and the 46° halo on October 20; and paraselenæ and lunar bar on August 22.

The *Zodiacal light* was noted on 19 evenings (very bright on March 9) and the zodiacal band on six evenings.

A bright display of the Aurora Borealis was seen on March 9.

The year 1926 was one of extremes. The minimum shade temperature recorded on January 17 (6°.3F.) was the lowest registered at the Radcliffe Observatory since 1878, December 24 (5°.6F.). A maximum temperature of 71°.6 was recorded on Good Friday, April 2, which is the earliest date in the year on which 70°F. has been reached since observations commenced here. The maximum temperature on September 19 was 85°.3F.; only once before has a temperature of 85°F. been recorded in the second half of September (85°.9F. on September 17, 1898). The latter half of October was unusually cold, the night of the 18th-19th being the coldest October night for 36 years. In only four previous Novembers (1839, 1842, 1852, 1894) has there been more rainfall since observations began in 1815, and the mean pressure for the month was the lowest on record. In only four previous Decembers (1835, 1844, 1853, 1883) has there been less rainfall, and the mean pressure was the highest recorded since 1879.

Correlation of Daily Rainfall on the East and West of Scotland.

The following note was suggested by reading an article in *British Rainfall* 1925, p. 254, by Dr. J. Glasspoole on "The relation between annual rainfall over Europe and that at Oxford and Glenquoich."

In that article is produced a map showing by means of isopleths the correlation coefficient between the annual amount of rainfall at Glenquoich (18 miles N. of Fort William) and other places in the British Isles. From our present point of view the important feature of this map is that the line of no correlation runs through the Moray Firth. This at first is surprising when we consider that until recently the same forecast district has included these places of no correlation of annual rainfall

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amounts and that generations of forecasters watching the daily weather maps have acquiesced in such a grouping of districts.

The present study is an experiment to find some satisfactory way of correlating the daily rainfall at two places. It is immediately obvious that to obtain a correlation coefficient in the ordinary way would be an absurdity. Two places, Kingairloch on Loch Linnhe, 20 miles S.W. of Fort William, and Achareidh, near Nairn, were chosen as representative of the very wet western Highlands and the dry eastern counties. For these two places the daily returns for 1926 were immediately available and the observations had evidently been made with great care. The rainfall at Kingairloch for the year was 108 inches and at Achareidh 25 inches.

Every day was given a character letter at each place, N, A, B or C, N denoting a day of no rain and A, B, C denoting increasing amounts. The limits of the amounts entitling a day to its particular character letter were so chosen for each place that the numbers of A, B and C days were as nearly as possible equal. The following table shows the limits allotted.

TABLE I.—Limits of Daily Rainfall for N, A, B, and C Days at Kingairloch and Achareidh.

	N.	A.	B.	C.
Kingairloch ...	0.00	.01in.—.16in.	.17in.—.49in.	.50in. and over.
Achareidh ...	0.00	.01in.—.03in.	.04in.—.10in.	.11in. and over.

Table II. shows the combination of the days at the two places and the total number of each character.

TABLE II.—Frequency Table of N, A, B, and C Days at Kingairloch and Achareidh.

		Kingairloch.				
		N.	A.	B.	C.	Total.
Achareidh.	N	81	25	17	11	134
	A	28	20	11	14	73
	B	19	17	23	21	80
	C	15	17	19	27	78
	Total	143	79	70	73	365

Table III. is produced as follows. There are 143 N days at Kingairloch, and these days are divided at Achareidh as follows:—

N.	A.	B.	C.
81	28	19	15

If the type at Achareidh were entirely independent of the type at Kingairloch, the numbers would be distributed in the ratio 134N, 73A. 80B, 78C, *i.e.*:—

N.	A.	B.	C.
53	29	31	31

Table III. shows the ratio of the actual distribution to the chance distribution.

TABLE III.—Ratio of Actual to the Chance Distributions of N, A, B, and C Days.

		Kingairloch.			
		N.	A.	B.	C.
Achareidh.	N	1.5	.9	.7	.4
	A	1.0	1.25	.8	.9
	B	.6	1.0	1.5	1.3
	C	.5	1.0	1.3	1.7

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We see that there is a strong tendency for days of similar character figures to occur at the two places, although combinations NC are not infrequent. Even if all rain fell from uniform rain belts which swept across the country unchanged, we could not have a perfect correlation between daily amounts because it must occasionally happen that rain would be allotted to one day at the first place and to the next day at the second place. Another factor operating in the same direction is the difference in the seasonal variation of the frequency of the types of day at the two places. The following table shows the frequency in each month for A and C days.

TABLE IV.—Monthly Frequency of A and C Days at Kingairloch and Achareidh.

Frequency A Days.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Kingairloch	6	6	3	4	7	7	8	8	12	3	6	9
Achareidh	8	9	4	6	5	3	4	6	7	5	9	7

Frequency C Days.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Kingairloch	13	8	7	2	2	3	3	9	5	7	8	6
Achareidh	4	5	8	6	7	11	7	4	7	9	7	3

It will be noticed that in general the frequencies are complementary at the two places. This makes the presence of factors such as 1.7 in Table III. very surprising, and there is little doubt that if similar figures were abstracted for a large number of years but treating each month separately, even larger factors would be obtained showing a very high correlation between the daily rainfalls on the east and west. Perhaps some reader tired of crossword puzzles will find time to do this. The seasonal variation of the degree of correlation would be a quantity of considerable interest.

R. A. Watson.

February, 1927.

Mammato-Cumulus Cloud at Cranwell, Lincolnshire.

1. The occurrence of mammato-cumulus cloud at Cranwell, Lincs., during the period from January 1, 1920, to October 12, 1926, has been analyzed, and in view of the rarity of the cloud in question it is thought that the results of that analysis may not be without interest.

2. Seasonal Distribution.

In the period considered there were 35 days upon which the cloud form in question occurred. Taking winter to include the months December, January and February, spring the months March, April and May, summer the months June, July and August, and autumn the months September, October and November, the seasonal distribution is shown in Table I.

TABLE I.—Seasonal Distribution of Mammato-Cumulus Cloud.

Season.	No. of days examined.	No. of days on which Ma.Cu. occurred	Percentage.
Winter	601	3	0.5
Spring	644	12	1.9
Summer	644	18	2.8
Autumn	588	2	0.3

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The table reveals that summer and spring in the order named are the seasons most marked by the occurrence of mammato-cumulus, and that in autumn and winter the cloud is seldom seen.

3. PRECIPITATION.

Of the 35 days upon which mammato-cumulus was observed, precipitation occurred at Cranwell on 27 of the occasions.

On only 14 of the 35 occasions did precipitation occur at the actual time of observation of the cloud.

Hail occurred on one of the 14 days with precipitation, accompanying the cloud, and in one other case within the hour following the occurrence.

4. THUNDERSTORMS.

On five of the 35 days of occurrence of the cloud, thunder was noted actually at Cranwell, but the *Daily Weather Reports* issued by the Meteorological Office, Air Ministry, show that on 12 of the days storms occurred in either the Midland or Eastern districts of England, these including the five cases of occurrence at Cranwell.

5. CUMULO-NIMBUS AND MAMMATO-CUMULUS.

On 23 of the 35 days of occurrence of mammato-cumulus, cumulo-nimbus was observed at some time or another.

On 15 occasions it both preceded and followed the occurrence of the mammato-cumulus; on five occasions it preceded only and on three it followed only.

6. LINE-SQUALLS AND MAMMATO-CUMULUS.

In three cases line-squalls occurred at Cranwell within the hour preceding the occurrence of the mammato-cumulus cloud. In no other case did line-squalls occur at any time during the day of its appearance.

7. PRESSURE TYPE AND MAMMATO-CUMULUS.

With regard to the map conditions prevailing, 25 of the 35 cases could be definitely associated with the rear of depressions, eight with the fronts of depressions, one with a col and one with an anticyclone, Cranwell being at the time in the centre of the system.

W. H. PICK.
G. A. WRIGHT.

Cranwell, Sleaford, Lincs.
February 17, 1927.

OBITUARY.

Mr. S. S. BURLINGHAM.

We learn with regret of the death of Mr. Samuel S. Burlingham, which took place on Sunday, January 2, 1927, from heart failure, which occurred after a brief attack of pleurisy from which he appeared to be recovering.

Mr. Burlingham was descended from old Quaker stock of Worcestershire origin, and was a well-known business man and active town worker at King's Lynn. A man of wide interests, his pursuits embraced geology, astronomy and meteorology, for which last science he maintained a series of observations extending over many years. He was of a genial and lovable disposition, while his catholic tastes made him a good and interesting companion.

He was elected a Fellow of this Society in 1919.

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Mr. J. C. Eckersley, M.A., J.P.

The death occurred in London on October 17, 1926, of Mr. James C. Eckersley, of The Manor, Carlton, Leeds.

Mr. Eckersley was first educated privately, proceeding later to Oxford University. Throughout his life he manifested a deep interest in church work and in educational affairs, and was a generous benefactor to many churches in the diocese of Liverpool, while his generous support placed the Hendley and Abram Grammar School on a secure footing.

He was a man of unassuming disposition and greatly preferred to do good in a quiet way.

He was elected a Fellow of this Society in 1900.

Mr. P. de Jersey Grut.

We regret to learn of the death of Mr. P. de Jersey Grut, which occurred in April, 1926, at Melbourne, Australia, at the age of 82 years.

He was elected a Fellow of this Society in 1912.

Mr. C. Harding.

With the death of Mr. Charles Harding, yet one more link with the early days of meteorology is severed.

Educated at Christ's Hospital and later at the City of London College, Mr. Harding entered the Meteorological Office, then a branch of the Board of Trade, in 1861. He served at first under Admiral Fitzroy in the general and forecast department, but later in the marine division, where he was principal assistant for 37 years. He retired in 1911, but returned for a time during the Great War.

He became a Life Fellow of the Society in 1874 and served on the Council and as a Vice-President for many years. He contributed about twenty papers to the *Quarterly Journal* and was for a long time a contributor on weather topics to the *Standard* and to the *Evening Standard*. For the *Shipping Gazette* he wrote over four hundred leading articles and in addition he made many contributions to the *Nautical Magazine* and to *Nature*.

He was one of the earliest contributors to Symons' British Rainfall, Mr. Symons being a colleague in the Office in the early 'sixties.

Mr. W. J. Harrison.

We regret to learn of the death of Mr. William J. Harrison, which occurred in London on November 19, 1926.

He was elected a Fellow of this Society in 1890.

Sir Robert Jardine.

The death occurred at Castle Milk of Sir Robert Jardine on January 30, 1927.

Sir Robert Jardine was born on January 21, 1868. He was educated at Eton and at Magdalene College, Cambridge. A member of the Jockey Club, his colours were well known, particularly in the North of England and in Scotland.

He was elected a Fellow of the Scottish Society in 1906.

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Mr. Edmund Pullar.

The death occurred on May 8, 1926, of Mr. Edmund Pullar, after a brief illness.

He was a busy man, but took a great interest in many things outside his business life, and anything of a scientific nature likely to make for progress was always assured of his cordial support.

He was elected a Fellow of this Society in 1909.

Dr. L. Pullar, LL.D.

The death occurred on December 23, 1926, of Dr. Laurence Pullar, at Dunbarney, Bridge of Allan.

Dr. Pullar was a lifelong friend of the late Sir John Murray of Challenger fame, and when Sir John became convinced that the survey of the British Isles could not be considered complete without a thorough sounding and mapping of the water areas, it was Dr. Pullar who, after the refusal of a Treasury grant, came to his assistance with a donation of £10,000. The work was unfortunately saddened by the death by drowning of Dr. Pullar's son Frederick, a promising engineer; but in spite of this severe loss the work was completed. The results were published in six large volumes under the joint editorship of Sir John Murray and Dr. Pullar, and contain surveys of no fewer than 562 Scottish lochs, together with descriptions of geological and other physical features and of the animal and vegetable life of the more important of them.

Dr. Pullar was elected a Fellow of the Scottish Society in 1872.

Miss E. D. Woodhouse.

We learn with deep regret of the death of Miss Woodhouse in tragic circumstances on September 7, 1926.

Miss Woodhouse was elected a Fellow of this Society in 1907.

Francis Campbell Bayard, LL.M.

Known to us mainly through his patient and exhaustive contributions to meteorology, we hardly think of F. Campbell Bayard as the successful barrister; the devoted head of a family; deeply interested in music; sharing to the full in district and county councils in the interests of his parish church; for thirty years an active member of the Farriers' Company; during the war applying his organizing powers to the administration of national funds for the relief of war distress.

Born at Richmond in 1851, that town was his home till he was twenty-six. After passing through Rugby he entered St. John's College, Cambridge in 1870, and in 1871 became a student in the Inner Temple. He was called to the Bar when twenty-five and practised successfully for many years.

Moving to Carshalton, he married in 1880. Mrs. Campbell Bayard and four of their six children survive him. The death two years ago of his son, Stephen Campbell Bayard, F.R.Met.Soc., in East Africa was a grievous shock to the father.

His removal to Wallington about 1885 was marked by his establishing a meteorological station with a complete set of instruments and making

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a special study of rainfall. This was carried on with his customary neatness and conscientious thoroughness until last year. He then entrusted his instruments to the Carshalton Urban District Council and the observations are being continued.

F. Campbell Bayard joined the Royal Meteorological Society in 1884 and began a series of valuable contributions to the *Proceedings*. He served on the Council from 1887 to 1915, and as one of the Honorary Secretaries from 1892 to 1897 and again from 1900 to 1915. He was president for the years 1898 and 1899.

One of his most outstanding meteorological activities began in 1888, when he organized, under the Croydon Natural History Club, the Croydon and District Rainfall Association. Beginning with 34 stations this grew to about 100, covering Surrey and West Kent. Until the last year or two the monthly reports gave the daily fall for nearly all the stations, but the reports ceased in 1925 on account of printing costs.

Apart from the wide interests of F. Campbell Bayard in civic and other duties, our Society will especially honour him as one of those who painstakingly and conscientiously laboured in laying truly the foundations of our science, upon which the later generation is now erecting that fuller comprehension of meteorological phenomena, so marked a feature of these latter years.

He died on January 22, 1927, at the age of 75 years.

J. Edmund Clark.

Lieut.-Col. Henry Mellish, C.B., D.L.

Very few can remember our Society before Henry Mellish became a Fellow, and he has been a familiar figure and a regular attendant at the meetings for a very great number of years. He was the son of Lieut.-Col. William Leigh Mellish, of Hodsock Priory, and Margaret, daughter of Sir Samuel Cunard, Bart. Born in 1856, he was educated at Eton and Balliol College, Oxford; there he obtained a first class in mathematics in Moderations and a first class in science in Honours in 1879. His interest in meteorology began before he left Oxford, and the meteorological observations at Hodsock Priory commenced just over fifty years ago. Mellish established a very complete climatological station, which included, besides the ordinary instruments, earth thermometers, a thermograph, and a recording raingauge. Adjoining the house at Hodsock is a fine Tudor gate house of brick, somewhat resembling those at St. John's and Christ's Colleges at Cambridge; on one of its turrets is a sunshine recorder, and a Robinson anemometer, whose revolutions can be counted by an electrical device in the study. For a number of years Mellish published a summary of his observations, and the summary for fifty years was published a year ago; that for the year 1926 had already been completed and was actually in the press at the time of his death.

Mellish joined the Royal Meteorological Society in 1876; he was elected to the Council in 1902, and served on it till 1925; he was President in 1909 and 1910. Despite his numerous engagements in Nottinghamshire he was perhaps the most regular attendant, not only at the Council meetings but at the meetings of the various committees on which he served. He was also a trustee of the British Rainfall Organization, and was a member of the committee which quite recently edited the new ***Rainfall Atlas of the British Isles***. But it was perhaps on the Finance

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Committee that his services should be particularly remembered; largely through his knowledge and advice the Society was safely brought through the difficult times after the war, and he had much to do with establishing the Society in its home in Cromwell Road.

Those who knew Mellish at the meetings of the Society realize how keenly he threw himself into the work of the Society, and with what thoroughness this work was done; but many do not perhaps realize that in very many other spheres his work was equally thorough; in fact, the amount of work that he managed to do can only be described as marvellous. He farmed a large acreage at Hodsock, and his interest in agriculture is shown in one of his presidential addresses on the "Relations of Meteorology with Agriculture." In Nottinghamshire he had been a member of the County Council since county councils were first instituted; he was for many years its vice-chairman and chairman of its Education Committee, and also represented the county on the County Councils Association for 36 years. He was a magistrate, and chairman of the North Notts Quarter Sessions. He was also chairman of the Notts Territorial Association from its beginning in 1908. He was always keenly interested in the volunteer and territorial movement; he had been in the school volunteer corps at Eton, he commanded a company of the volunteer corps at Oxford, and subsequently held a commission in his county battalion, which he later on commanded; after the term of his command came to an end, when most men would have retired on their laurels, he reverted to the rank of major and served in the corps for another seven years. He was a first-class rifle shot from the time he was at Eton to the end of his life, and won many prizes; he shot in the English VIII. for the Elcho Shield twenty-six times, first in 1882 and lastly in 1921; he never missed the meetings at Wimbledon and Bisley from 1872 to 1926. For thirty years he was on the council of the National Rifle Association. His interest in rifle shooting led him to set up an experimental range at Hodsock, with a ballistic pendulum, and the results of consequent investigations appeared the year before last in "The Hodsock Ballistic Tables for Rifles" by Mr. F. W. Jones, to which Mellish contributed the preface. He was also a keen sportsman and an excellent shot with a sporting gun.

For many years he rode a bicycle, and on many days each month he did part of the journey to Nottingham in this way, till a few years ago, when, by doctor's orders, he gave up a bicycle for a motor, which he usually drove himself. When he had to go into Nottingham he had to start from home before the hour for the meteorological readings, but when he was at home he took the readings himself. He always copied the readings himself into the daily and monthly record books, and filled up the weekly, monthly and yearly returns to the Meteorological Office. On the last day of his life he took the readings himself, and died just after entering the house, with the observation book in his hand.

He seemed perhaps somewhat stern to those who did not know him well; but this was an external trait due perhaps to a certain shyness, for he was the most unassuming of men. He has been described as universally trusted and loved, noted for a perfect integrity of character, and a modesty entirely free from self-seeking.

C. J. P. C.

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REVIEWS.

The Eastern North Atlantic. By BJORN HELLAND-HANSEN and FRIDTJOF NANSEN. *Oslo, Geofysiske Publikasjoner,* Vol. 4, No. 2, 1926. Pp. 76. Illus. Pris 12 kroner.

The physical character of the ocean masses and their behaviour has always been a subject of absorbing interest not only to oceanographers, and to those whose business it is to navigate the seven seas, but also to meteorologists, who cannot fail to realize the far-reaching influence that ocean currents exert on the atmosphere. This aspect of meteorology is a particularly vital one for weather-men of Europe, the continent which stems, so to speak, the heated flood waters of the North Atlantic.

If we trace the development of our hydrographical knowledge of the North Atlantic, we find that Lieutenant Maury, of the U.S. Navy, in the middle of the last century, with the aid of thousands of mariners' records, mapped the general scheme of circulation. The neatly engraved plates in our school geographies, showing a smooth, clockwise gyral dominating the North Atlantic, are eloquent testimony to the work, and to Maury's followers. This school of physical oceanography deals with observations almost wholly related to the surface of the sea. During the last half of the nineteenth century, however, the improvement and invention of various deep-sea instruments and gear made it possible for oceanographers to study not only the surface, but explore down to the very ocean beds themselves. Physical oceanographers of late years have more and more been applying the mathematical formulæ of free motion to the dynamic tendencies of ocean masses, and thereby developing a practical method of mapping currents over wide areas. This is the outstanding feature of the recently published contribution by Helland-Hansen and Nansen. The results of their work reveal more clearly than we have ever seen before the manner in which the waters from the tropics are disposed as they approach the western shores of Europe.

Most of the deep-sea observations which form the basis of the illustrations in the present treatise were made from the auxiliary motor schooner *Armauer Hansen,* a vessel about 72 feet long and 9 feet draft, owned and operated by the Bergen Museum under the immediate direction of Professor Bjorn Helland-Hansen. Many people not familiar with the sea might have misgivings of such a small craft for this off-shore work, but on the contrary she embodies several ideal qualities. I can personally testify to a very lively spring cruise across the Norwegian shelf, north of the Faroes, in 1925, yet I could not help but admire the manœuvring abilities of this little craft, especially while hove-to, taking a station. It was possible at all times to keep the wire from which the instruments are suspended practically vertical, a requirement which is very difficult to meet, with a large vessel.

The *Armauer Hansen* made a total of five cruises, viz., 1913, 1914, 1922, 1923 and 1924, to the eastern North Atlantic waters, sailing during some of these years as far west as the 30th meridian, and as far south as the Azores-Madeira-Gibraltar line. Stations were located at critical points where observations of the temperature, salinity, oxygen content, and hydrogen-ion concentration were determined. Twice during these years off-shore current meter observations have been made. Meteorological observations and biological collections were part of the programme but not during every summer. The results of the temperature and the salinity observations are the material discussed in *The Eastern North Atlantic.*

In order to obtain a more accurate and conclusive picture of physical conditions prevailing in the area surveyed, the authors have included all

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sub-surface data of temperature and salinity, previously collected, provided these met the modern requirements of accuracy. For example, it was largely by means of the observations taken by the *Michael Sars* in 1910 that the position of the Atlantic current west of the 30th meridian has been plotted. Other oceanographic records found useful are those from the German expeditions, *Deutschland* and *Möwe*, in 1911.

The authors evidently feel that the meat of the matter is contained in a reference and reading of the plates, as nearly half the book is given over to detailed illustrations of the distribution of temperature, salinity, and density, both in vertical profile along the more important lines of stations and in horizontal projection. The charts giving the distribution of the anomaly of salinity are interesting as showing graphically the manner in which water from the Mediterranean spreads west and north, particularly at depths of 1,000 to 1,200 metres, out of the Straits of Gibraltar. The normal correlation curve of temperature and salinity is based on the material collected by the *Michael Sars* from the North Atlantic in 1910.

A considerable section of the text is devoted to a discussion of the vertical oscillation of water layers. Attention was called to this phenomenon by Helland-Hansen and Nansen in 1909,[1] and the observations taken off the European coast in 1914 and 1923 also clearly indicate such a rise and fall, verifying earlier statements. These oscillations appear to have definite periods connected with the tides, but how a tidal wave can produce such great vertical movements in the different strata seems to the authors at present quite inexplicable. Here is an important problem for oceanography. Individual observations, therefore, may not represent prevailing conditions, and so in interpreting the charts the general trend of the curves is the point to follow and not the minor details. In the present survey the fact that observations at two or more stations in the same place, but separated by years, agree fairly well is evidence that these observations, at least, represent normal conditions.

The topographic maps carried as the conclusion of the publication form a really noteworthy advance in physical oceanography. These charts show the contour of the chosen decibar surface relative to that of the 2,000 decibar surface, which is the one employed at the base plane. If there is no motion on the 2,000 decibar surface (approximately 2,000 metres) and the authors believe there to be none, then the contour lines connecting equal dynamic values, at the other depth, will be the stream lines of the gradient current, provided that the accelerating force of friction is negligible. All motion is, therefore, included in the calculations except that due solely to wind-friction in the surface layers.

No attempt is made here to delineate the circulation in the upper 100 metres, probably because of the fluctuations and vagaries to which the top film is subject. The movement of this top film, however, ultimately approximates to the behaviour of the underlying masses.

Helland-Hansen and Nansen find that the Atlantic current approaching Europe flows eastward across the mid-Atlantic longitudinal ridge between parallels 49 and 46, then turns southward and divides, apparently guided by the bottom configuration on the eastern slope of the ridge. The larger branch turns abruptly northward and later rounds Rockall Bank to the westward before entering the Norwegian Sea. The southern branch of the Atlantic current flows southward, passing just east of the Azores, thence crosses towards Madeira, and then follows the elevations and series of banks that lie towards the continent. The highest velocities, averaging fifteen miles per day, were found on or near ridges, as for example in the southern branch between Madeira and Gibraltar.

[1] Helland-Hansen and Nansen. "The Norwegian Sea." Kristiania, 1909. Report on Norwegian Fishery and Marine-Investigations, Vol. **2**, 1909, No. 2.

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One of the object lessons of this work is the astonishing effect of bottom configuration on the direction and velocity of ocean currents. Another map combining these two features would have been an effective illustration. Another important lesson here is the tendency for the currents to hug closely to the slopes where impelling forces exist, and this is a quite different picture from the gentle regular sweep of the circulation usually shown on our maps of the North Atlantic.

Delineating the dynamic topography of the oceans, at least in their main features, is a new and promising field unfolding in physical oceanography. If oceanographers will conduct further surveys similar to these just completed in the eastern North Atlantic, meteorologists, placing their hands, so to speak, on the pulse of the main arteries prevailing in the sea, will be better able to correlate phenomena in the atmosphere with variations in oceanic circulation. E. H. S.

Rain Making and other Weather Vagaries. By W. J. Humphreys. London, Bailliére, Tindall & Cox; Baltimore, The Williams and Wilkin Co. 8vo. Pp. x + 157. 11s. 6d.

Dr. Humphreys has written a book that should be read by a very wide public. The idea of controlling the weather is one that is constantly cropping up in one form or another, and even some who ought to know better raise false hopes which as far as can be seen have no basis in fact. The human race is dependent on weather for its very existence, and the opening sentence of Professor Humphreys's book "Give us food lest we perish" is, as he says, the most compelling of all human cries. Thus there is a widespread tendency for primitive man to try to bring rain during droughts, and to stay the fall of rain during wet periods, and Dr. Humphreys gives a short account of how it was thought possible to bring about rain by imitating rain, thunder and lightning, by bloodletting, and by mimicking aquatic birds and animals, and to bring about fine weather by the use of fire, drying wet objects, and by keeping oneself dry. Readers of the "Golden Bough" will know how widespread and various are such practices. Dr. Humphries then considers what he classifies as religious attempts at control of the weather, the chief of which comes under the heading of prayer. Though not mentioned by him, both the Church of England and the Roman Catholic Church have forms of prayer for rain and for fine weather, but it is very much to be doubted whether those who use them have any idea of what it is they are asking for. It would be less a miracle to remove a mountain by prayer than by the same means to bring rain in a dry spell, or dry weather in a rainy one. To achieve such ends, vast masses of air would have to be moved against the natural forces that were acting at the moment; if we could see the air, and so have some idea of the mechanical problem involved, everyone would, I think, agree that such things were outside the province of prayer, and that it would be bordering on impiety to ask for them. "If it is argued, the pious farmer or the minister for him can obtain rain by prayer, why can he not also, in the same way, have stumps and stones, for instance, removed from his fields, or any other desired end accomplished?"

But it is with what Dr. Humphreys calls the scientific methods of weather control that he is chiefly concerned. We hear of these methods to some extent in this country, but they seem to flourish even more in America. The idea that a battle is followed by rain is far older than firearms, for it is mentioned by Plutarch. It may have originated in the bloodletting, which was an imitative charm often used by primitive man when he wanted rain, or in the noise of battle, for noises were also used as rain spells. In more recent times, however, there has been a popular

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idea that the actual concussion of the guns "brought down the rain." But if the concussion of the guns at Waterloo, or even at a sham fight with blank cartridges, could produce rain, the whole question ought to have been placed beyond doubt during the Great War; and yet there is no proof that any rain was due to the violent bombardments of those days. Naturally rain on some occasions followed battles, but the disturbance to which it was due was approaching beforehand, and certainly on one occasion the rain had begun to fall in the west before the first shot was fired in an engagement in the North Sea. Dr. Humphreys gives a somewhat similar case in which "after a bombing séance near Battle Creek, Michigan, a shower occurred that immediately was heralded abroad as incontestable proof that rain could be obtained from the clouds by merely jarring them with a little dynamite. But those who joyously made these claims overlooked the fact that on that day rain fell all the way from the Pacific Ocean to the Great Lakes and beyond." Yet in spite of all that has been written a large section of the public still believes that, given sufficient detonations, rain will follow, and this in spite of the fact that there is no sort of proof that a concussion can have any physical effect of a rain-producing kind. The cause of rain is fairly well understood; it is known that no heavy rain can fall without rising air. Dr. Humphreys calculates what work would be necessary under fairly normal conditions to obtain artificially half an inch of rain over the sixty square miles of the district of Columbia, and he finds that it is of the order of 75 million horse-power for an hour. As he points out, there are times, when convection is active, when it would be easier to produce this amount of rain, but on the other hand when rain is most needed the conditions are apt to be far worse than those supposed in his calculation. Various methods are then considered which, theoretically, might produce rain, or obtain water from the atmosphere, such as fires, making a cold barrier, fog-catching screens, cooling the free air, "dusting the sky," electrically charging and discharging the air, and sprinkling the clouds with electrified sand; in all these methods he finds that the mechanical and engineering problems are far and away beyond the powers of man; in the words of a Japanese proverb quoted on the title page, "A fog cannot be dispelled by a fan." Even the clearing of a fog from an aerodrome is shown to be out of the question. And having shown how puny are man's efforts, he concludes the first part of his book by describing "How Nature makes a drought" and "How Nature produces rain."

In the second part of the book "Other Weather Vagaries" are discussed, such as the supposed influence of the planets and the moon; and he shows conclusively that each of these ideas is a "mumpsimus-chronic error immune to reason." He deals similarly with key or control days, of which the most familiar in this country is St. Swithin's, but there are a number of other days which in one country or another have been considered as key days. Various other weather fallacies will be found in this book; in fact, one wonders in reading this account of them that so many are still current in civilized countries. The disadvantage of the wide currency of false ideas is that people pay all too little attention to real weather signs and reputable weather forecasts. When one considers how often these so-called weather signs must be wrong, it seems extraordinary that they can still maintain their time-honoured position. It must be supposed that one success makes more impression on the ordinary mind than a number of failures. But Dr. Humphreys's book should dispel many wrong ideas about the weather, and it is to be hoped that it may prevent public bodies from spending money on attempts at weather control. Money has been so squandered in various countries, including the United States, and we ourselves have only narrowly escaped. The book deserves a very wide circulation.

C. J. P. C.

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The Divining Rod: An Experimental and Psychological Investigation. By Sir WILLIAM BARRETT, F.R.S., and THEODORE BESTERMAN. London (Methuen & Co. Ltd.), 1926. Pp. xxiii + 336 + 12 plates. 18s. net.

The Charter of the Royal Society states that it was established for the improvement of *Natural* science. "Natural" was originally intended to imply a meaning which is probably not commonly known. When the Society came into being, divination and witchcraft were encouraged extensively and the word "natural" was introduced in contradistinction to supernatural.

We must be grateful to Sir William Barrett that he did not construe strictly the Charter of the Society of which he was a Fellow, or a most readable and interesting book might not have been published. Unfortunately, death prevented him from completing the classification and discussion of all the collected data which had entailed, we are told in the preface, the writing of between 6,000 and 7,000 letters.

Mr. Besterman, who had for some time been closely in touch with Sir William, accepts responsibility for the arrangement and writing of the book.

In Part I., extending over some sixty pages, the historical and geological aspect of dowsing is dealt with. The rise of the art is traced back to the fifteenth century, when it was in use not only for discovering water and minerals, but for tracking criminals.

Somersetshire, owing to its geological formation, and Cornwall, in a lesser degree, appear to have produced the most eminent dowsers. It is, however, made quite clear that none of the dowsers had any real geological knowledge.

Part II., "Experimental," comprises the larger part of the work, and Appendices B and C might quite well have been incorporated into it.

Famous British dowsers of the nineteenth century, and notable contemporary British and foreign ones, both professional and amateur, are dealt with, and their various exploits set out.

Amongst a large number of successes in water divining in England and Ireland, perhaps the most striking one is that at Bath. During the drought year of 1921 the water supply of Bath was found to be wholly inadequate, various attempts to increase the supply having failed, and by 1922 the position had become serious. Two plans were under consideration, either of which would have cost £100,000 and taken three years to complete. Before one of the schemes was adopted, the dowser, H. W. Mullins, one of the famous John Mullins's sons, was called in. He went in great detail over the area, reported an adequate water supply to be available, and subsequently the work was entrusted to him. The cost of the finding of water by the dowser was £5,463 as against £100,000, and the time taken to make the supply available was a few months, instead of three years.

Experiments with two or more independent dowsers and with the dowser blindfolded are interesting.

Part III., "Theoretical," embraces the mechanism and rationale of dowsing. Most dowsers work with some kind of rod. Such a rod may be simply a natural one formed of a twig branching into two, or it may be a manufactured article resembling a spur. The distinguishing characteristic of these forked rods is that such a rod has three extremities, which correspond to the angles of an imaginary triangle, of which two are held one in either hand, the third one pointing away from the body. Some dowsers dispense with any form of rod, and use only their bare hands, either stretched out horizontally to the earth or clasped together. Sufficient evidence is adduced by the authors to establish the fact that the rod in the hands of the dowser moves, often violently, and without the volition of the dowser.

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Most of the dowsers when exercising their art assert that when the rod moves in their hands, or when they believe that underground water is beneath them, they experience a peculiar sensation, which some describe as felt in the limbs like the tingling of an electric shock, and others as a shaking or trembling. One is tempted to inquire whether there is any connection between the malaise of the dowser and the disturbed state, experienced by some people, on the approach of thundery weather conditions.

Finally, the authors arrive at the conclusion that no physical theory can cover the facts of dowsing. In their opinion, the dowser is a person endowed with a subconscious, supernormal cognitive faculty of an unknown nature, and they adopt the term, after Professor Richet, of cryptesthesia. By means of this hidden perception, knowledge of whatever is searched for enters the dowser's subconsciousness, and is revealed by means of an unconscious muscular reaction, less often by an obscure nervous sensation or emotion producing physiological disturbances, and very rarely by means of direct supernormal cognition made conscious by a visualization or hallucination.

The discovery is required of some fruitful generalization permitting the orthodox scientist to incorporate cryptesthesia into the canon of accepted and indisputable scientific knowledge.

There is an excellent index and a very extensive bibliography.

Recently, the Department of Agriculture, Bombay, has described (*Bulletin*, No. 72, 1915, revised 1925) the results of official tests carried out by mechanical water-finding apparatus: The mechanism is either secret or not clearly described, but depends on the horizontal deflection of a magnetic needle, set in the magnetic meridian, when placed directly above a flowing stream of underground water. The observations were carried out in the Trap rocks of the Deccan, where the entire water supply is from native wells, forty per cent. of those sunk being failures. All the wells sunk at the spots indicated by the apparatus were successful. Reference is also made to successes in the State of Indore. It appears possible that further investigations with these mechanical water-finders may throw light on the physical basis of dowsing.

SPENCER RUSSELL.

Zum Klima der Türkei: Heft I., Luftdruck und Winde im östlichen Mittelmeergebiet. By Dr. LUDWIG WEICKMANN. 1922. Pp. 114. *Heft II., Die Temperaturverhältnisse der Türkei. Der Scirocco.* By Dr. PEREGRIN ZISTLER. 1926. Pp. 181. 8vo. Leipzig, Geophysikalisches Institut der Universität. *Heft III., Die Ergebnisse der deutschen Höhenwindmessungen im Palästina* 1917-1918. By HARALD KOSCHMIEDER. Pp. 30. Frankfurt a.M. Universitäts druckerei.

From 1915 to 1918 the Germans took control of many public departments in Turkey, including the weather service, and this is the origin of the books before us. The three years' observations have been worked up by the meteorologists who directed the service. This in itself is a great advantage, and by combining all available previous data the authors have produced an elaborate and very interesting and useful account of the climate of Turkey in Europe and more especially of Turkey in Asia, Syria, Palestine, and the north of Mesopotamia. The war came to an end before their stations could be extended, as the authors had hoped, to the shores of the Persian Gulf.

Part I. contains good maps of the mean isobars and prevailing winds in January, April, July and October for the whole Mediterranean basin and surrounding region. For the other months the maps are on a smaller scale and cover only the eastern Mediterranean. They are based on means for 1878-1913; the sources of the data and the conscientious

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attempts to correlate those from different countries are explained in the first few chapters. The difficulties of such a correlation are well known, and we are again forcibly reminded of the great waste of time caused by the failure to co-ordinate hours and conditions of meteorological observations, to say nothing of the lack of precision and even the serious errors that result from the use of data that are not strictly comparable; this matter would still seem to offer scope for useful activity in international meteorological congresses.

A most valuable feature is the prominence given to the daily weather sequence. Typical weather types are described and illustrated by actual pressure, temperature and humidity traces.

Continental influences come very near to the Mediterranean in the Levant. There are three main continental controls. In winter, the great anticyclone over the interior of Asia pours vast streams of cold air over S.W. Asia towards the Black Sea, the Cyprus region and the Persian Gulf, where low pressure systems tend to hang over the warm water. In summer the dominating feature is that of the low-pressure system over southern Asia. The air currents over the whole Mediterranean region are envisaged as westerly winds blowing into it from the Azores high pressures. There are many local variations, one of the most important being the Etesian winds which flow steadily from the north over Greece and the Ægean Sea. The wind reversal from east in winter to west in summer is described as a great monsoon, hardly less impressive than that of the Indian Ocean, but this would seem to be straining the term monsoon, which connotes more than a mere reversal of wind direction. The third continental influence is that of the hot deserts of N. Africa and Arabia, which provide the hot scirocco winds in spring and autumn.

The most important part of the work is the discussion of the pressure irregularities and their effects. The cyclone tracks and frequencies have been established and mapped for the east Mediterranean region as far as the available material allows. The map of cyclone tracks together with their frequencies forms, as the authors say, a fairly complete picture of the climate. Clearly the observations are not yet numerous enough to give certainty, and we note that there are serious discrepancies between these results and those based on the Egyptian meteorological reports, a reminder of the inaccuracy of the outlying parts of daily isobar maps; it is not only in such lean meteorological regions as Asia Minor that disagreements are to be found between the maps of different services.

The plateau block of Asia Minor is shown to have an interesting effect in splitting many of the cyclones reaching it from the west, part continuing past the Sea of Marmora into the Black Sea and part skirting the southern shores of Asia Minor. The main results established are that cyclones are very few indeed in summer, two or three only in the three months, but numerous in winter, a new one appearing every five days with fair regularity. Autumn and spring have almost as many as winter. But in the Cyprus region there are not nearly so many in autumn as in spring, the weather in autumn being notably settled and very warm, and the rains that, in that season, are necessary for successful agriculture in Syria and Palestine are liable to be late or to fail altogether. The spring cyclones which pass along the south coast of Asia Minor are the cause of thunderstorms, especially frequent owing to topographical influences and sharp temperature contrasts along the south of the Taurus, where the mountains, still snow-covered, meet the hot plains of Syria.

A feature which is to a certain extent novel is the representation of the prevailing winds by continuous lines of flow. In drawing the lines the speed and constancy of the winds were ignored, so that the lines are little more than a generalization from the isolated arrows denoting not very numerous observed directions.

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In Part II. the main climatic regions are described separately with special reference to temperature. Numerous weather types are described in detail and illustrated by maps of isobars and traces of temperature and humidity. It is a testimony to the assiduity of the authors that this region, which was until recently one of the least known and for which the available climatic statistics were very scanty, has been described so fully.

The work ends with a long account of scirocco winds which are a familiar visitation all round the Mediterranean. The different meanings that have been given to the term scirocco are examined, and detailed descriptions of numerous examples with excellent maps of isobars and traces of temperature and humidity, and in some cases upper air soundings, leave no room for further confusion as to the characteristics and origin of these winds. The conclusion reached is that the scirocco is essentially a desert wind, which occurs not only round the Mediterranean but on the outskirts of hot deserts everywhere. It is normally very hot, dry and dusty, but after passing over the sea it is moist and warm, as in Italy, and may give heavy rain. The immediate cause is the passage of a depression into which the hot desert air is drawn, giving a temporary reversal of the more usual wind direction from the cold to the warm area.

W. G. K.

Le Climat des Alpes Française. By ERNEST BÉNÉVENT. *Ministère des Travaux Publics. Memorial de l'Office National Météorologique de France,* publié sans la Direction du Général Delcambre. Paris, 1926. Size 12 x 10, pp. 435, maps and illustrations.

This extensive treatise embodies not only instrumental data, but also a large amount of information about the climate of the region derived from the author's personal observations and intercourse with the mountain people, and has taken twelve years to complete. In a volume so ponderous the advantages of a light and attractive style of writing will be readily apparent, and throughout one is brought to realize the extraordinary local complexities of climate of the mighty mountain system, the French section of which is dealt with in this book. As with so many French works, the treatment is highly concise and systematic, all the meteorological elements discussed being comprised under the categories of Winds, Temperature and Humidity, which form, respectively, the First, Second and Third Parts. But it would almost appear that the fear of violating this plan has debarred the author from giving any specific account of such composite phenomena as thunderstorms, notwithstanding the prominence of these in the Alps.

In the First Part we have an account of the major relations of wind and pressure which affect this part of Europe, together with a description of the various winds to which local names have been given and the pressure conditions associated therewith. Such winds include the well-known Föhn, a Southerly wind; the Bize and Mistral, the cold Northerly winds of the northern and southern section respectively; the Levant and Marin, South-Easterly winds of the southern section; the Vent du Midi, the South-Westerly wind of the northern section; the Lombarde, a South-Easterly current along the Italian Border in the northern section; and the Traverse and Labech, North-Westerly and South-Westerly currents in the northern and southern sections respectively. Steady rain or snow often accompany the Vent du Midi and Marin, whereas the Traverse and Labech bring typical "cold-front" torrential rains of short duration with thunder and hail. It is satisfactory to find these various winds explained in relation to the general pressure distribution, because the danger of using specific names for winds, whether in the Alps or elsewhere, is that one tends to form conceptions thereof which are too hard

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and fast. The question is not whether a given Southerly wind either is or is not a "Föhn" or a Northerly wind a "Mistral," but rather *to what extent* such a wind conforms to the generalization implied in the category.

In the part dealing with temperature we are shown isothermal maps reduced to sea-level, and also, as far as it were possible to construct them, true isotherms. Obviously in a region of high and bold relief the elimination of the altitude and configuration factors of climate is only of significance in presenting a picture of the influences due to latitude and continentality or oceanity, and it is a rather doubtful picture at that, since in high mountains it is problematical whether the reduction factors are at all accurately known.

There are tables showing, for various places, the average number of days when the maximum air temperature reaches or exceeds 30°C. (86°F.) and when the minimum falls to −10°C. (14°F.) or below. Spells of great heat are rare in the northern section of the French Alps, excepting in the low-lying valleys, but they are more frequent in the southern section except along the Mediterranean littoral. The cyclonic type of "heat wave" is of short duration; the anticyclonic type persistent. Spells of severe cold are frequent in the Northern Alps excepting in the low valleys, and are also frequent in the high interior valleys of the Southern Alps. The Russian anticyclonic type brings persistent cold, the Atlantic anticyclonic type short frosts.

The part which deals with humidity includes the discussion of fog, cloudiness, rainfall and snowfall, but not of vapour pressure or of relative humidity.

The isohyetal maps reveal an exceedingly complex geographical distribution of mean annual rainfall in the French Alps. The fundamental factors in the distribution are latitude (the mean annual rainfall decreasing generally from the Savoy Alps in the north to the Provenzal Alps in the south) and local relief, but there is also a gradual decrease from the exterior to the interior parts of the chain away from the influence of the sea. We may note that whereas in the wide area of the British Isles the determining factor in the geographical distribution of mean annual rainfall is relief, showing that the whole area is similarly situated with regard to the moisture-bearing Atlantic winds, the marked decrease from north to south in the limited extent of the French Alps is an expression of the fact, referred to later, that the northern and southern sections of the French Alps belong to different climatic provinces, the former being dominated by the Atlantic and the latter by the Mediterranean. In general, neither the mean annual amounts of rain, nor the number of rain-days, particularly the latter, are anything like as great as in the mountainous part of the British Isles, at all events at moderate elevations. The seasonal variation of the rainfall in the different sections of the Alps is fully discussed. Periods of drought or excessive rain appear to be less felt in the southern Alps than in the northern, because the south is more or less habituated to summer drought, whilst the wet spells are less severe than in the north.

The snowfall and its effects on the life of the mountaineers is treated of at considerable length. Notwithstanding that the French Alps rise well above the snow-line (at about 8,000 feet) and are drained by large glaciers, it is stated that the study of the snowfall has been comparatively neglected as compared with the rainfall. A characteristic of the snowfall of the French Alps is said to be its capriciousness, some years being marked by enormous quantities, others by comparatively little. It is instructive to note that at elevations in the French Alps comparable with those of the Scottish Grampians, the number of days in the year on which snow falls is much smaller, and there are no figures in a whole list of stations at 4,000 to 5,000 feet above sea-level at all comparable with

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A chapter on the effects of the winter snowfall in the high mountain valleys above 5,000 feet is fascinating reading. The mountaineers are for from five to eight months every year literally buried in snow and must make ample provision in the autumn for food and fodder. Sometimes a metre of snow will be deposited in one downfall. There is also the danger of avalanches and tourmentes, which latter, apparently, are blinding squalls of eddying snow-drift. In spite of the heavy snowfall, however, the winter weather is said to be characteristically bright and sunny.

Lastly, it must be pointed out that M. Bénévent's work is not merely a description; it is a thesis. Step by step in every section of the book we are led up to the proposition with which the book concludes, namely, that the French Alps, though only traversing some 3° of latitude, are divided into two distinct climatic zones by a line running east and west approximately through Briançon, a little south of the 45th parallel. The Northern Alps are marked off from the Southern as belonging to a different regimen of winds and precipitation, and as having a different quality of sunlight and atmosphere. The immediate cause of this contrast is the frequent location of an axis of high pressure across the middle of the range separating the Atlantic system of Westerly winds of the north from the Mediterranean system of the south with winds mainly from the east. The Alps of Savoy are humid and cloudy, with tempered sunlight, those of Provence arid and clear with the glaring sunlight of the south. And the difference of climate is reflected in the character of the mountain landscape. The northern peaks are frequently enveloped in mist, and their slopes are comparatively gentle and heavily forested, whereas the southern mountains are generally clear and their contours steep with a more arid type of vegetation. One may say, perhaps, that the Northern French Alps begin to show those humid climatic features which attain their full development in North-Western Europe, and the Southern French Alps the arid features which are most accentuated on the African shores of the Mediterranean.

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VOL. 53.] JULY, 1927 [No. 223

TURBULENCE.

By Prof. G. I. TAYLOR, F.R.S.

(Fellow and Lecturer in Mathematics, Trinity College, Cambridge; Yarrow Research Professor of the Royal Society.)

[The G. J. Symons Memorial Lecture delivered before the Royal Meteorological Society, March 16, 1927.]

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Turbulence is an irregular motion which in general makes its appearance in fluids, gaseous or liquid, when they flow past solid surfaces or even when neighbouring streams of the same fluid flow past or over one another. The actual motion is usually so irregular that very little is known of its details. No one really knows exactly how or why turbulence arises, though something is known about the conditions which must be satisfied in order that a fluid may flow without turbulence or in "stream-line" motion as it is called. On the other hand, the effects of turbulence on the average properties of the fluid are frequently quite easy to measure and to study without going into any details of the actual structure of the motion of the eddying fluid.

An obvious analogy to this position is furnished by the study of the physical properties of gases. The kinetic theory of gases teaches us that they owe their measurable physical properties like temperature, pressure, etc., to the fact that they consist, in detail, of atoms flying in all directions and continually colliding with one another, but a great deal can be learnt about the relationship between pressure, temperature and other physical properties of a gas without knowing anything at all about the details of the atomic motions.

The average effect of turbulence in a fluid is to endow it with the power of diffusing certain properties through the fluid. It is known that fluids at rest possess this power, water vapour can be transmitted through a gas by diffusion and heat by conductivity. When a fluid is flowing in stream-line, non-turbulent motion, each

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layer drags the neighbouring layers along owing to its stickiness or viscosity. The fluid therefore has the property of transmitting momentum from one layer to the next. It appears, therefore, that without the intervention of turbulence, air possesses in itself the power of diffusing the three physical properties which are of greatest interest to meteorologists, namely, heat, momentum and water-vapour-content. One naturally asks, therefore, is the study of diffusivity due to turbulence of any greater importance to meteorologists than the study of the diffusing power of air at rest?

To answer this question one must take account of the rates at which diffusion takes place. The diffusivity of air due to turbulence varies according to the nature of the ground, the wind-velocity, the temperature gradient and so forth, but on the average one may say that water vapour, temperature and momentum are transmitted through the atmosphere about 100,000 times as fast as they would be in air at rest or in stream-line motion. For this reason, therefore, turbulence produces large effects on the motion and condition of the atmosphere to which conductivity, diffusivity or viscosity in non-turbulent air could not give rise.

In order to illustrate my meaning I am going to show you an experiment, due originally to Osborne Reynolds. The apparatus, which is shown in Fig. 1, consists of a channel with glass sides

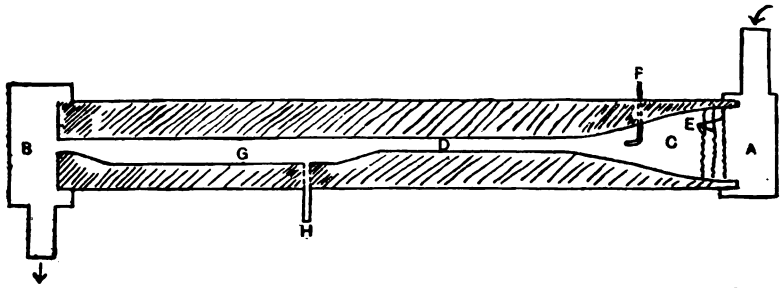

FIG. 1.—Diagram of apparatus showing turbulent motion and effect of stratification of density in suppressing turbulence.

which can be placed in front of a lantern and projected on to a screen. Water flows through a converging entrance C into the parallel part D. A small jet (F) of water coloured with eoscene (red ink) is placed in the converging part, and the lower end, which is bent at right angles, is set so as to point down stream. At slow speeds of flow the motion is non-turbulent and a thread of colouring matter is carried down stream. This thread is subject to diffusion and it must therefore be slightly broader down stream than it is at the place where it is first injected, but this broadening is so slight that one cannot detect it by eye in the length available in the apparatus.

When the speed of flow is increased the motion remains stream-line till quite suddenly, at a certain speed, it becomes turbulent. The thread of colouring matter is then diffused within a few centimetres of the point of injection into a broad band which nearly fills the channel, thus illustrating the enormous difference between the diffusing power of turbulent and non-turbulent air.

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As a further illustration of this great difference I may mention the effect of turbulence in diffusing momentum and hence, dissipating energy in tidal streams at sea. It has long been known from astronomical observations that the earth is gradually slowing down in its rotation round its axis and, consequently, the day is slowly lengthening. This is an effect that must be due to some kind of tidal friction, but whether it is due to friction of bodily tides inside the earth or to tides in the ocean was not at first clear. Calculations based on a knowledge of the viscosity of sea water in stream-line motion showed that only an infinitesimal fraction of the effect could be due to friction unaided by turbulence. Some years ago, however, I found a way in which the rate of dissipation of tidal energy in limited basins can be calculated from tidal observations. Applying this to the Irish Sea, I found that the amount of energy dissipated there is many thousands of times as great as could possibly be accounted for by tides flowing in streamline motion. It is in fact one-fiftieth of the amount necessary to account for the observed slowing down of the earth. Continuing this work, Dr. Jeffreys surveyed all the limited basins in the world where tidal energy might be expected to be dissipated and he came to the conclusion that the dissipation is just about what is required by the astronomers. It appears, therefore, that turbulence in the ocean is really responsible for a phenomenon on such a vast scale as the gradual slowing down of the earth's rotation.

The experiment you have just seen illustrates the difference between stream-line and turbulent motion, but, so far, I have said nothing about why the motion was stream-line at slow speeds and turbulent at high speeds. The explanation of this was given by Osborne Reynolds, who showed that viscosity has the effect of tending to prevent turbulence from being formed. One can, for instance, run glycerine or oil very much faster than water through a pipe without causing the stream-line motion to break down. On the other hand, the larger the pipe the lower the speed of flow at which turbulence sets in; so that the flow of the atmosphere over the earth's surface, which may be likened to that of air in a very large pipe, might be expected to be turbulent at a very low wind-speed indeed. Now, though viscosity seems to have no appreciable moderating effect on turbulence in the atmosphere, the effect of density distribution is very marked. On a clear night, for instance, when the air near the ground gets cold and, therefore, heavy, turbulence is prevented because the wind has not sufficient energy to raise the heavy air up from the ground and replace it by lighter air from above, an effect which would be a necessary consequence of the existence of turbulence.

I have a slide (Fig. 2) which shows this effect very clearly. The upper curve is a thermograph record of the temperature near the ground during a week of fine weather in July, 1916. It will be seen that there is a large drop every night except on the night of the sixth, which was rather cloudy. On that night there was a smaller drop in temperature.

Some corresponding records of the Dines pressure tube anemometer installed on the top of Pyestock chimney (130ft. high) are also shown in Fig. 2. It will be seen that the mean wind at 130ft.

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remains almost constant and equal to about 10 or 12 miles per hour during the whole week. On the other hand, on the nights of the 5th, 8th and 9th when there were large falls in temperature the eddy motion had been almost completely suppressed by the density distribution. On the night of the 6th, however, the fall in temperature was much less, and the eddy motion, though less than in the day, was still appreciable throughout the night.

The power of density stratification in the air to prevent the formation of turbulence has been expressed in mathematical form

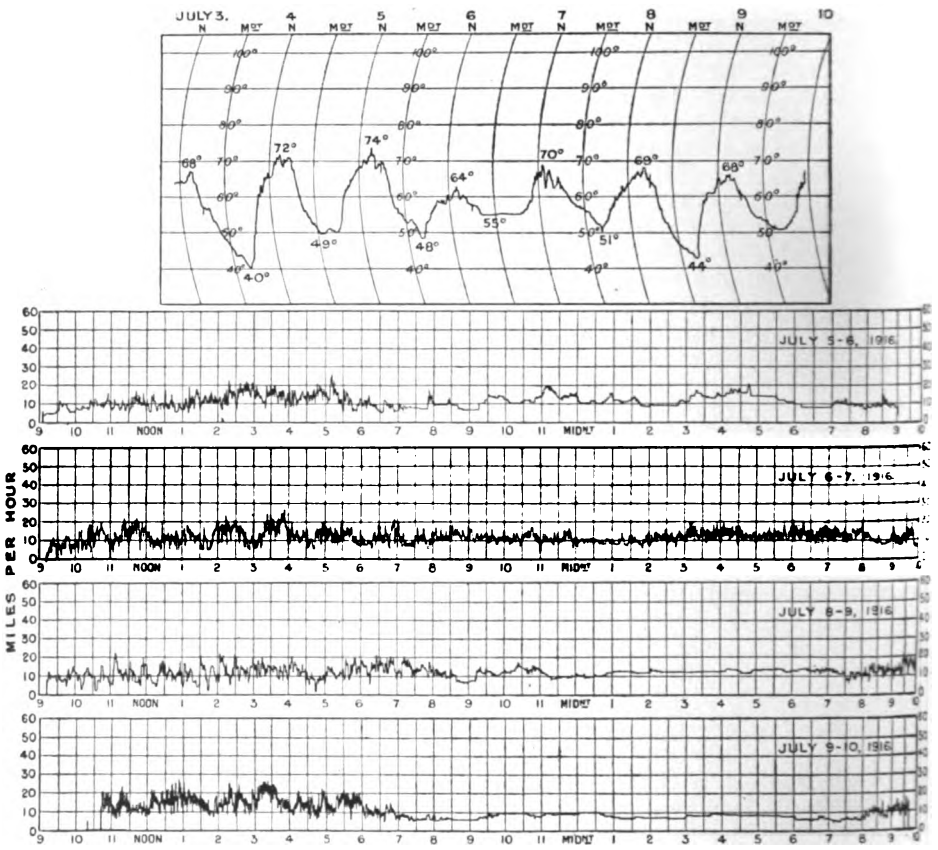

FIG. 2.—Records showing effect of density stratification in suppressing turbulence at a height of 130 feet.

by Mr. Richardson, and I am going to illustrate it by means of an experiment with the apparatus you have just seen.

In this experiment coloured brine, which is heavier than water, is run into the apparatus through a pipe H (Fig. 1) and it collects in the shallow trough which takes the form of a local deepening of the channel. The flow of the water carries off a little brine from the surface and this is replaced by a slow continuous flow of brine into the apparatus. At slow speeds the surface of separation between the brine and the clear stream above it remains quite sharp.

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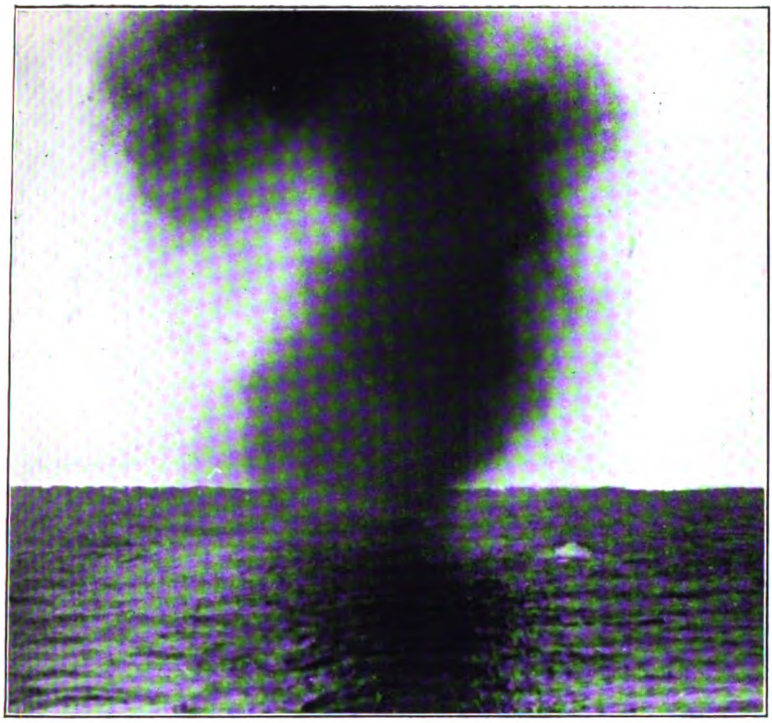

FIG. 3.—Puff of smoke emitted from steam funnel.

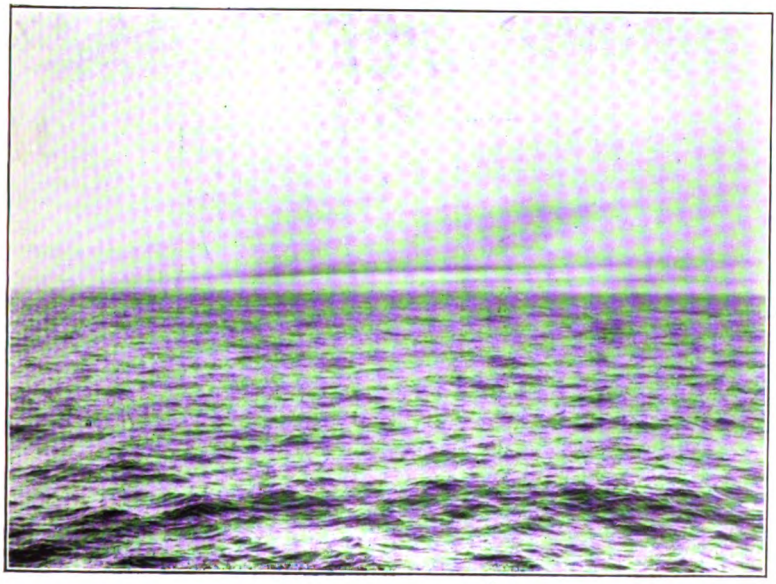

FIG. 4.—The same puff of smoke 15 minutes later.

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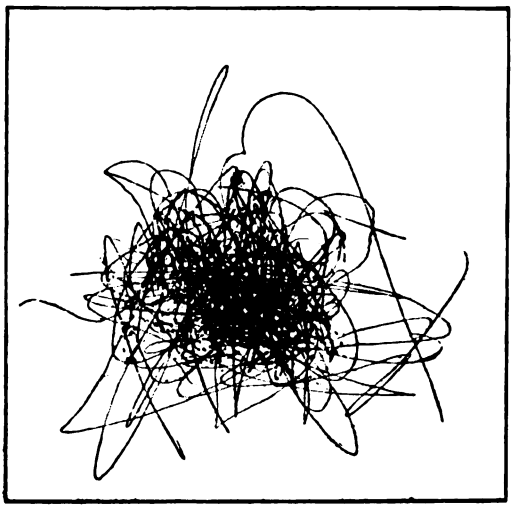

FIG. 8.—Record of vertical and cross-wind eddy components at height of 25 feet above grass land.

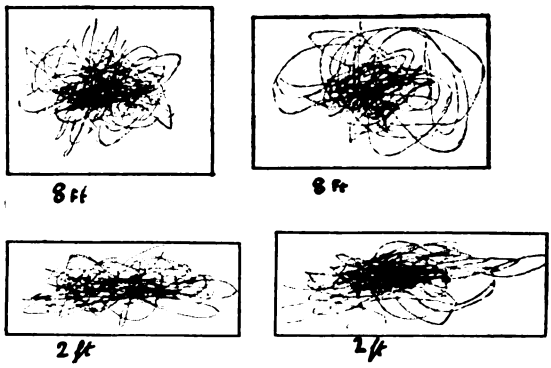

FIG. 9.—Records of vertical and horizontal eddy components at heights of 8 feet and 2 feet above a ploughed field.

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As one increases the speed the upper liquid first becomes turbulent as in the previous experiment. The surface of separation remains quite sharp however, showing that the density distribution has stopped the formation of turbulence in the lower fluid. As the flow increases in speed the surface of separation begins to get slightly agitated, but still remains distinct. By careful adjustment one can get quite a high speed with no turbulence in the lower layer of brine, but suddenly turbulence sets in and the whole of the brine is swept out of the apparatus. The experiment may, perhaps, be regarded as an illustration of the way in which a cold and frequently misty patch of air lying in a hollow is suddenly blown away by a rising wind in the higher layers.

As another illustration of the way in which a stratification of density prevents the formation of turbulence I have made a slide of two photographs which I took in 1913 on the Newfoundland Banks. The first (Fig. 3) shows a puff of smoke emitted from the steamer on which I was travelling when the stoker put on a bucket of coals. It forms an ill-defined column about 60ft. high. There was a moderate wind, sufficient, as the original of the second photograph shows, to break the tops off some of the small waves. In these circumstances the smoke would, under ordinary conditions, have been dispersed in a few minutes. At the time, however, there was a very intense stratification of density. The upper air was warm and the sea was nearly freezing; some small lumps of ice floating in it can be seen in the photograph. These conditions had the effect of suppressing turbulence almost completely with the result that the smoke patch was still visible as a compact mass after half an hour. Fig. 4 shows a photograph taken after 15 minutes. It will be seen that the velocity gradient has pulled the patch out into a narrow sloping band, but that it has not become at all diffuse, the lower edge especially being very sharply defined. Under the puff in Fig. 4 will be seen another puff drawn out into a very fine line. This puff was emitted half an hour before the photograph was taken.

We may now pass on to consider the effects of turbulence on the condition of the atmosphere. In a general way we can see the nature of the mechanism by which turbulence is capable of transferring localised properties of air through the atmosphere. Consider, for instance, dry air flowing from the land over the sea. The lowest layer of air quickly becomes saturated with moisture. Turbulence then removes portions of this saturated air and replaces it with dry air from above. The saturated air mixes with the dry air at the level to which it is raised by turbulence, thereby producing a layer of air whose moisture content is intermediate between the saturated air in contact with the sea and the dry air above. In this way a vertical gradient of moisture is formed.

The dry air above and the sea below maintain this gradient while turbulence is continually trying to eliminate it. One may say in general that, wherever there is a gradient of temperature or water vapour content, turbulence will transfer the heat from the high temperature to the low or water vapour from the places of high vapour pressure to the places of low vapour pressure. It seems clear that the amount of heat transmitted is proportional to the vertical temperature gradient for any given distribution of turbulence

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In Part II. the main climatic regions are described separately with special reference to temperature. Numerous weather types are described in detail and illustrated by maps of isobars and traces of temperature and humidity. It is a testimony to the assiduity of the authors that this region, which was until recently one of the least known and for which the available climatic statistics were very scanty, has been described so fully.

The work ends with a long account of scirocco winds which are a familiar visitation all round the Mediterranean. The different meanings that have been given to the term scirocco are examined, and detailed descriptions of numerous examples with excellent maps of isobars and traces of temperature and humidity, and in some cases upper air soundings, leave no room for further confusion as to the characteristics and origin of these winds. The conclusion reached is that the scirocco is essentially a desert wind, which occurs not only round the Mediterranean but on the outskirts of hot deserts everywhere. It is normally very hot, dry and dusty, but after passing over the sea it is moist and warm, as in Italy, and may give heavy rain. The immediate cause is the passage of a depression into which the hot desert air is drawn, giving a temporary reversal of the more usual wind direction from the cold to the warm area.

W. G. K.

Le Climat des Alpes Française. By ERNEST BÉNÉVENT. *Ministère des Travaux Publics. Memorial de l'Office National Météorologique de France,* publié sans la Direction du Général Delcambre. Paris, 1926. Size 12 x 10, pp. 435, maps and illustrations.

This extensive treatise embodies not only instrumental data, but also a large amount of information about the climate of the region derived from the author's personal observations and intercourse with the mountain people, and has taken twelve years to complete. In a volume so ponderous the advantages of a light and attractive style of writing will be readily apparent, and throughout one is brought to realize the extraordinary local complexities of climate of the mighty mountain system, the French section of which is dealt with in this book. As with so many French works, the treatment is highly concise and systematic, all the meteorological elements discussed being comprised under the categories of Winds, Temperature and Humidity, which form, respectively, the First, Second and Third Parts. But it would almost appear that the fear of violating this plan has debarred the author from giving any specific account of such composite phenomena as thunderstorms, notwithstanding the prominence of these in the Alps.

In the First Part we have an account of the major relations of wind and pressure which affect this part of Europe, together with a description of the various winds to which local names have been given and the pressure conditions associated therewith. Such winds include the well-known Föhn, a Southerly wind; the Bize and Mistral, the cold Northerly winds of the northern and southern section respectively; the Levant and Marin, South-Easterly winds of the southern section; the Vent du Midi, the South-Westerly wind of the northern section; the Lombarde, a South-Easterly current along the Italian Border in the northern section; and the Traverse and Labech, North-Westerly and South-Westerly currents in the northern and southern sections respectively. Steady rain or snow often accompany the Vent du Midi and Marin, whereas the Traverse and Labech bring typical "cold-front" torrential rains of short duration with thunder and hail. It is satisfactory to find these various winds explained in relation to the general pressure distribution, because the danger of using specific names for winds, whether in the Alps or elsewhere, is that one tends to form conceptions thereof which are too hard

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and fast. The question is not whether a given Southerly wind either is or is not a "Föhn" or a Northerly wind a "Mistral," but rather *to what extent* such a wind conforms to the generalization implied in the category.

In the part dealing with temperature we are shown isothermal maps reduced to sea-level, and also, as far as it were possible to construct them, true isotherms. Obviously in a region of high and bold relief the elimination of the altitude and configuration factors of climate is only of significance in presenting a picture of the influences due to latitude and continentality or oceanity, and it is a rather doubtful picture at that, since in high mountains it is problematical whether the reduction factors are at all accurately known.

There are tables showing, for various places, the average number of days when the maximum air temperature reaches or exceeds 30°C. (86°F.) and when the minimum falls to −10°C. (14°F.) or below. Spells of great heat are rare in the northern section of the French Alps, excepting in the low-lying valleys, but they are more frequent in the southern section except along the Mediterranean littoral. The cyclonic type of "heat wave" is of short duration; the anticyclonic type persistent. Spells of severe cold are frequent in the Northern Alps excepting in the low valleys, and are also frequent in the high interior valleys of the Southern Alps. The Russian anticyclonic type brings persistent cold, the Atlantic anticyclonic type short frosts.

The part which deals with humidity includes the discussion of fog, cloudiness, rainfall and snowfall, but not of vapour pressure or of relative humidity.

The isohyetal maps reveal an exceedingly complex geographical distribution of mean annual rainfall in the French Alps. The fundamental factors in the distribution are latitude (the mean annual rainfall decreasing generally from the Savoy Alps in the north to the Provenzal Alps in the south) and local relief, but there is also a gradual decrease from the exterior to the interior parts of the chain away from the influence of the sea. We may note that whereas in the wide area of the British Isles the determining factor in the geographical distribution of mean annual rainfall is relief, showing that the whole area is similarly situated with regard to the moisture-bearing Atlantic winds, the marked decrease from north to south in the limited extent of the French Alps is an expression of the fact, referred to later, that the northern and southern sections of the French Alps belong to different climatic provinces, the former being dominated by the Atlantic and the latter by the Mediterranean. In general, neither the mean annual amounts of rain, nor the number of rain-days, particularly the latter, are anything like as great as in the mountainous part of the British Isles, at all events at moderate elevations. The seasonal variation of the rainfall in the different sections of the Alps is fully discussed. Periods of drought or excessive rain appear to be less felt in the southern Alps than in the northern, because the south is more or less habituated to summer drought, whilst the wet spells are less severe than in the north.

The snowfall and its effects on the life of the mountaineers is treated of at considerable length. Notwithstanding that the French Alps rise well above the snow-line (at about 8,000 feet) and are drained by large glaciers, it is stated that the study of the snowfall has been comparatively neglected as compared with the rainfall. A characteristic of the snowfall of the French Alps is said to be its capriciousness, some years being marked by enormous quantities, others by comparatively little. It is instructive to note that at elevations in the French Alps comparable with those of the Scottish Grampians, the number of days in the year on which snow falls is much smaller, and there are no figures in a whole list of stations at 4,000 to 5,000 feet above sea-level at all comparable with

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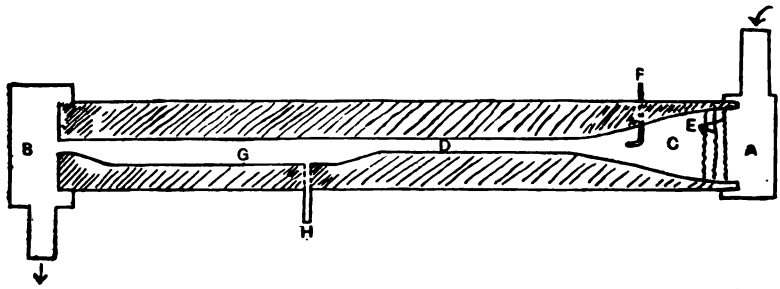

FIG. 1.—Diagram of apparatus showing turbulent motion and effect of stratification of density in suppressing turbulence.

which can be placed in front of a lantern and projected on to a screen. Water flows through a converging entrance C into the parallel part D. A small jet (F) of water coloured with eoscene (red ink) is placed in the converging part, and the lower end, which is bent at right angles, is set so as to point down stream. At slow speeds of flow the motion is non-turbulent and a thread of colouring matter is carried down stream. This thread is subject to diffusion and it must therefore be slightly broader down stream than it is at the place where it is first injected, but this broadening is so slight that one cannot detect it by eye in the length available in the apparatus.

When the speed of flow is increased the motion remains stream-line till quite suddenly, at a certain speed, it becomes turbulent. The thread of colouring matter is then diffused within a few centimetres of the point of injection into a broad band which nearly fills the channel, thus illustrating the enormous difference between the diffusing power of turbulent and non-turbulent air.

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As a further illustration of this great difference I may mention the effect of turbulence in diffusing momentum and hence, dissipating energy in tidal streams at sea. It has long been known from astronomical observations that the earth is gradually slowing down in its rotation round its axis and, consequently, the day is slowly lengthening. This is an effect that must be due to some kind of tidal friction, but whether it is due to friction of bodily tides inside the earth or to tides in the ocean was not at first clear. Calculations based on a knowledge of the viscosity of sea water in streamline motion showed that only an infinitesimal fraction of the effect could be due to friction unaided by turbulence. Some years ago, however, I found a way in which the rate of dissipation of tidal energy in limited basins can be calculated from tidal observations. Applying this to the Irish Sea, I found that the amount of energy dissipated there is many thousands of times as great as could possibly be accounted for by tides flowing in streamline motion. It is in fact one-fiftieth of the amount necessary to account for the observed slowing down of the earth. Continuing this work, Dr. Jeffreys surveyed all the limited basins in the world where tidal energy might be expected to be dissipated and he came to the conclusion that the dissipation is just about what is required by the astronomers. It appears, therefore, that turbulence in the ocean is really responsible for a phenomenon on such a vast scale as the gradual slowing down of the earth's rotation.

The experiment you have just seen illustrates the difference between stream-line and turbulent motion, but, so far, I have said nothing about why the motion was stream-line at slow speeds and turbulent at high speeds. The explanation of this was given by Osborne Reynolds, who showed that viscosity has the effect of tending to prevent turbulence from being formed. One can, for instance, run glycerine or oil very much faster than water through a pipe without causing the stream-line motion to break down. On the other hand, the larger the pipe the lower the speed of flow at which turbulence sets in; so that the flow of the atmosphere over the earth's surface, which may be likened to that of air in a very large pipe, might be expected to be turbulent at a very low wind-speed indeed. Now, though viscosity seems to have no appreciable moderating effect on turbulence in the atmosphere, the effect of density distribution is very marked. On a clear night, for instance, when the air near the ground gets cold and, therefore, heavy, turbulence is prevented because the wind has not sufficient energy to raise the heavy air up from the ground and replace it by lighter air from above, an effect which would be a necessary consequence of the existence of turbulence.

I have a slide (Fig. 2) which shows this effect very clearly. The upper curve is a thermograph record of the temperature near the ground during a week of fine weather in July, 1916. It will be seen that there is a large drop every night except on the night of the sixth, which was rather cloudy. On that night there was a smaller drop in temperature.

Some corresponding records of the Dines pressure tube anemometer installed on the top of Pyestock chimney (130ft. high) are also shown in Fig. 2. It will be seen that the mean wind at 130ft.

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remains almost constant and equal to about 10 or 12 miles per hour during the whole week. On the other hand, on the nights of the 5th, 8th and 9th when there were large falls in temperature the eddy motion had been almost completely suppressed by the density distribution. On the night of the 6th, however, the fall in temperature was much less, and the eddy motion, though less than in the day, was still appreciable throughout the night.

The power of density stratification in the air to prevent the formation of turbulence has been expressed in mathematical form

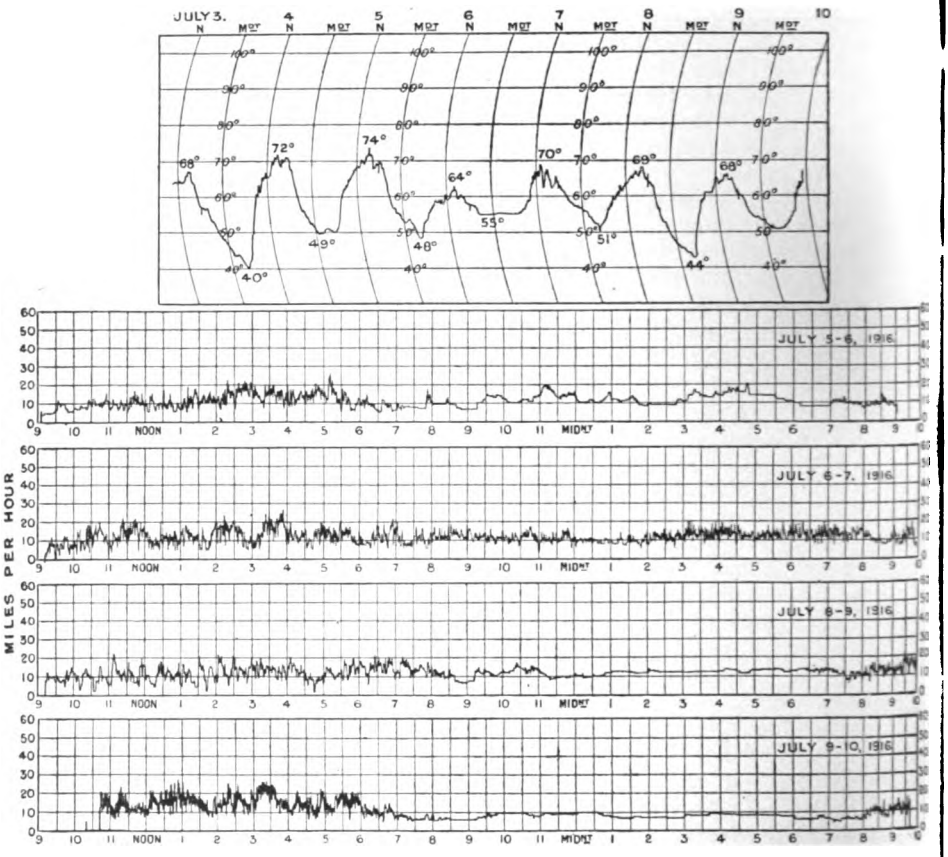

FIG. 2.—Records showing effect of density stratification in suppressing turbulence at a height of 130 feet.

by Mr. Richardson, and I am going to illustrate it by means of an experiment with the apparatus you have just seen.

In this experiment coloured brine, which is heavier than water, is run into the apparatus through a pipe H (Fig. 1) and it collects in the shallow trough which takes the form of a local deepening of the channel. The flow of the water carries off a little brine from the surface and this is replaced by a slow continuous flow of brine into the apparatus. At slow speeds the surface of separation between the brine and the clear stream above it remains quite sharp.

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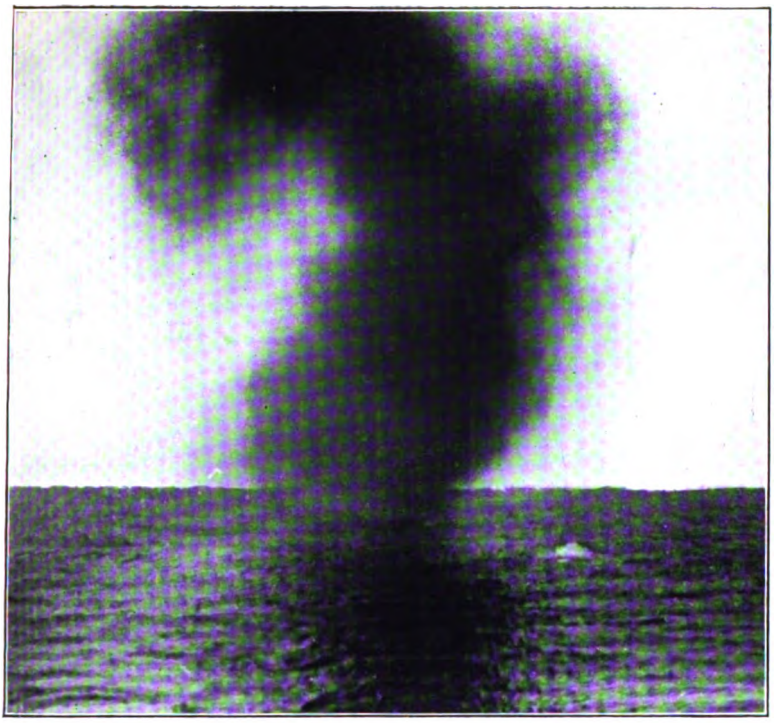

FIG. 3.—Puff of smoke emitted from steam funnel.

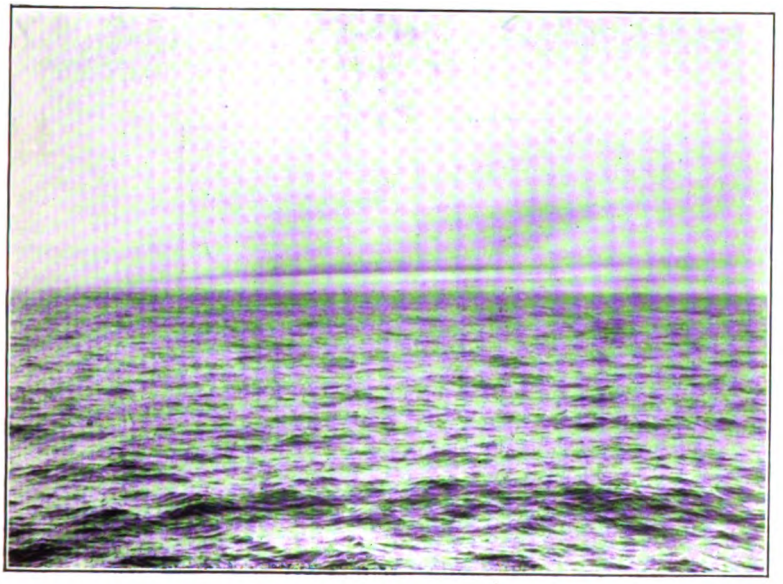

FIG. 4.—The same puff of smoke 15 minutes later.

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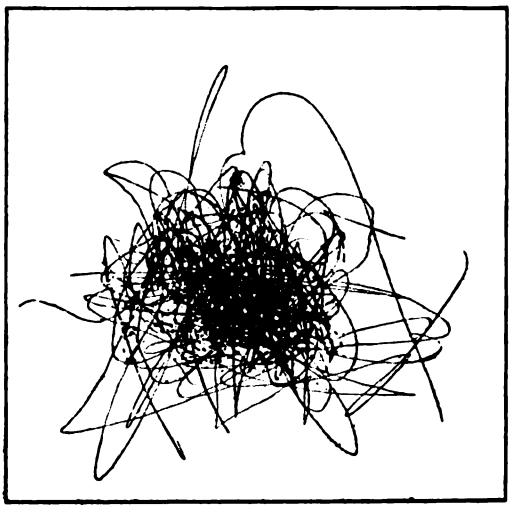

FIG. 8.—Record of vertical and cross-wind eddy components at height of 25 feet above grass land.

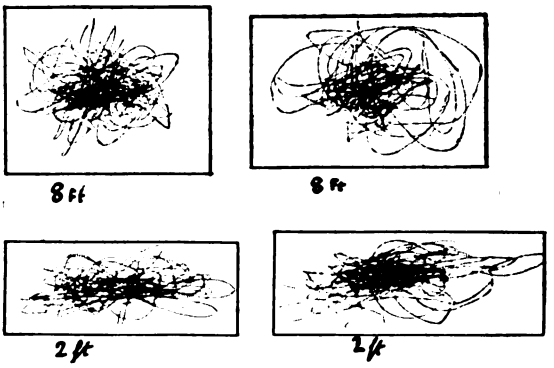

FIG. 9.—Records of vertical and horizontal eddy components at heights of 8 feet and 2 feet above a ploughed field.

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As one increases the speed the upper liquid first becomes turbulent as in the previous experiment. The surface of separation remains quite sharp however, showing that the density distribution has stopped the formation of turbulence in the lower fluid. As the flow increases in speed the surface of separation begins to get slightly agitated, but still remains distinct. By careful adjustment one can get quite a high speed with no turbulence in the lower layer of brine, but suddenly turbulence sets in and the whole of the brine is swept out of the apparatus. The experiment may, perhaps, be regarded as an illustration of the way in which a cold and frequently misty patch of air lying in a hollow is suddenly blown away by a rising wind in the higher layers.

As another illustration of the way in which a stratification of density prevents the formation of turbulence I have made a slide of two photographs which I took in 1913 on the Newfoundland Banks. The first (Fig. 3) shows a puff of smoke emitted from the steamer on which I was travelling when the stoker put on a bucket of coals. It forms an ill-defined column about 60ft. high. There was a moderate wind, sufficient, as the original of the second photograph shows, to break the tops off some of the small waves. In these circumstances the smoke would, under ordinary conditions, have been dispersed in a few minutes. At the time, however, there was a very intense stratification of density. The upper air was warm and the sea was nearly freezing; some small lumps of ice floating in it can be seen in the photograph. These conditions had the effect of suppressing turbulence almost completely with the result that the smoke patch was still visible as a compact mass after half an hour. Fig. 4 shows a photograph taken after 15 minutes. It will be seen that the velocity gradient has pulled the patch out into a narrow sloping band, but that it has not become at all diffuse, the lower edge especially being very sharply defined. Under the puff in Fig. 4 will be seen another puff drawn out into a very fine line. This puff was emitted half an hour before the photograph was taken.

We may now pass on to consider the effects of turbulence on the condition of the atmosphere. In a general way we can see the nature of the mechanism by which turbulence is capable of transferring localised properties of air through the atmosphere. Consider, for instance, dry air flowing from the land over the sea. The lowest layer of air quickly becomes saturated with moisture. Turbulence then removes portions of this saturated air and replaces it with dry air from above. The saturated air mixes with the dry air at the level to which it is raised by turbulence, thereby producing a layer of air whose moisture content is intermediate between the saturated air in contact with the sea and the dry air above. In this way a vertical gradient of moisture is formed.

The dry air above and the sea below maintain this gradient while turbulence is continually trying to eliminate it. One may say in general that, wherever there is a gradient of temperature or water vapour content, turbulence will transfer the heat from the high temperature to the low or water vapour from the places of high vapour pressure to the places of low vapour pressure. It seems clear that the amount of heat transmitted is proportional to the vertical temperature gradient for any given distribution of turbulence

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so that one may roughly represent the amount of heat transmitted as being equal to a multiple K_c of the gradient of heat content. This number K_c one may call the eddy-conductivity. It is analogous to the physical conductivity which all gases possess divided by the heat capacity per unit volume, but it is, numerically, enormously greater than the corresponding quantity for air at rest.

In the same way we may define an eddy-diffusion coefficient K_d as being the ratio of the rate of diffusion of water-vapour to the gradient of water-vapour content.

One of the fundamental properties of eddy-diffusivity is that $K_c = K_d$. One can see at a glance why this should be the case. The heat and water-vapour are carried about in an eddying fluid by the same eddies. Any portion of the fluid which becomes detached from its surroundings and is carried in the turbulent motion to another stratum of the air carries its heat and its water vapour with it. If, for instance, in the example previously considered the dry air flowing over the sea were warmer than the sea, coldness would be removed upwards by the same agency as water vapour and an exploring kite flown some miles out to sea would show that the height to which the water vapour had extended would be exactly equal to the height to which the cold air had penetrated.

It is usually difficult to obtain direct meteorological evidence of the truth of this, but in certain cases where the changes in temperature and humidity of the surface air occur simultaneously and are large, the effect is shown very definitely in the temperature and humidity measurements made by kites or pilot balloons.

I noticed several cases during the voyage of the *Scotia* in the summer of 1913 when the ship was cruising on the Banks of Newfoundland. In that region the sea is cold and the air at a few hundred metres is frequently very dry and warm as a result of passing over the mainland of America. One of these cases is shown in Fig. 5. It will be seen that the humidity curve on the left

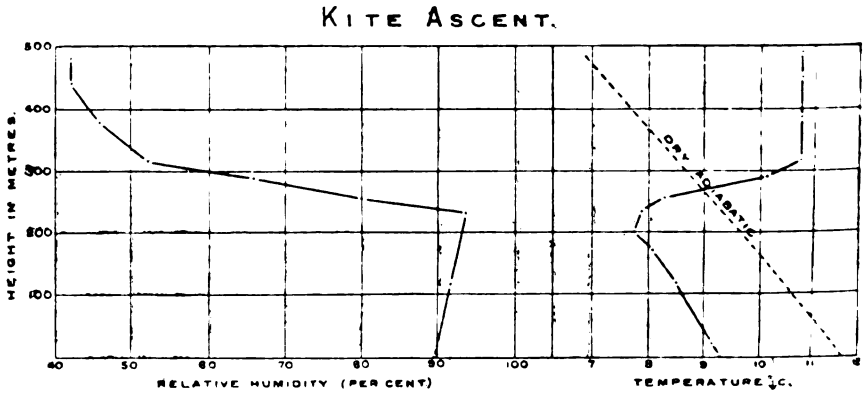

FIG. 5.—Temperature and Humidity over the Banks of Newfoundland.

follows very closely the temperature curve on the right, and that the moisture from the sea and the cooling due to the low temperature of the sea have both extended up to a height of 230 metres. At

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that height there is a sudden fall in water vapour content and a rise in temperature.

Transfer of Momentum.

Besides water vapour and temperature it seems clear that turbulence also transfers momentum from the atmosphere into the ground. The friction of the wind on the ground is equal to the rate at which momentum is conveyed downwards. If we suppose that momentum is a property which is conveyed through the atmosphere in exactly the same way as heat, then there would be a direct relationship between the rate at which heat is removed from the ground and the friction of the wind on the ground. This view, which was originally put forward by Osborne Reynolds, is widely believed to be true, though, as Rayleigh pointed out, there is no theoretical reason why it should be. Momentum is in fact not a property which can be regarded as being attached to any given portion of a fluid and carried with it in eddying motion. Pressure variations exist in turbulent motion and these serve to increase or decrease the momentum in an eddy independently of that in the layer from which the eddy arose.

It may be that local variations of pressure in eddying motion produce no effect on the mean rate of transfer of momentum, so that the capacity of the turbulent motion for diffusing momentum is the same as that for diffusing heat and water vapour. As a matter of observation they are, in fact, of the same order of magnitude but it is not possible to say that they are equal. For example, the daily changes of temperature at the earth's surface are propagated upwards, producing a daily range of temperature which decreases at increasing heights. From the observed temperature ranges at various heights up the Eiffel Tower, for instance, one can calculate the power of the turbulent air between the ground and the top of the tower to diffuse heat. This may be represented by a number whose mean value is about 10×10^4 in C.G.S. units.

From the variation of wind direction at different heights up the Eiffel Tower one can also calculate the diffusing power of the same air for momentum. This can be represented by a number whose mean value is about 7.6×10^4. It will be seen that these two numbers are of the same order of magnitude, though whether they should really be equal is still undecided.

General Characteristics of Turbulent Motion.

So far, I have described only the observations in which the diffusing power of turbulence is deduced from measurements of mean conditions, *i.e.*, mean velocity, mean temperature, etc. When one comes to think about the details of turbulent motion or about the actual mechanics of the process by which a fluid is endowed with diffusive power one is faced with apparently insuperable difficulties on account of the complexity of the motion. One cannot hope, for instance, to represent the motion by any mathematical expression giving in detail the velocity and direction of motion at any point. On the other hand, there are characteristics of turbulent motion other than its diffusing power which one can measure and to which one can assign average values. In a search for these

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one is limited by the type of instruments available. Here it will be noticed that, for measuring the effect of the diffusing power of turbulence on the average conditions in an eddying fluid, laboratory experiments may be more suitable than meteorological observations because the conditions are more under control and the observer is able to repeat his experiment. On the other hand, for detailed observation of turbulent motion the enormous scale of the motion in meteorological phenomena makes it possible to use instruments which follow the details of the motion, whereas in laboratory experiments the eddies follow one another in such rapid succession that no instrument in ordinary use can follow them.

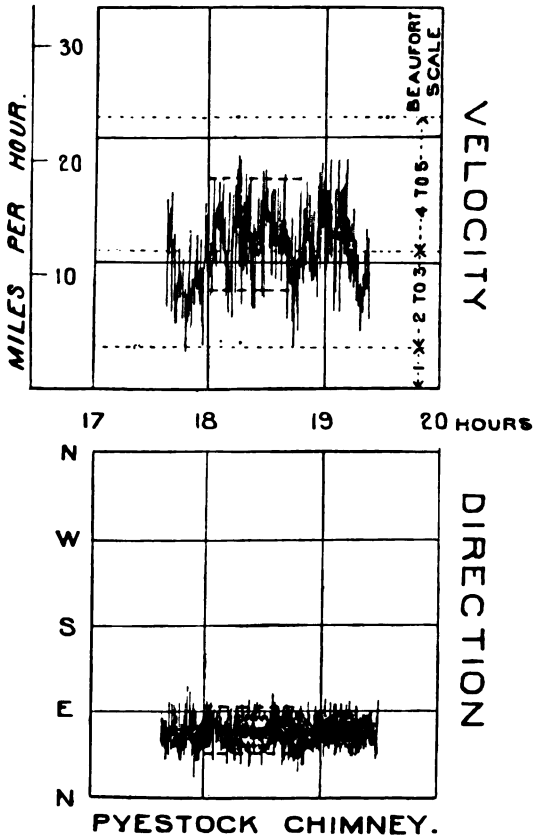

FIG. 6.—Velocity and Direction records from Pyestock Chimney.

The characteristics of eddy motion most suitable for measurement are the greatest variations in strength of the wind, wind direction and barometric pressure. Some years ago Dr. T. E. Stanton made an instrument with which he could record the variation of static pressure and the variation in wind velocity at a given point. On examining his records he was unable to find any direct connection between the two. The places of high pressure did not correspond with the places of maximum or minimum velocity. In a

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fluid moving under the influence of a distribution of pressure which is fixed in space, as, for instance, a fluid moving steadily past a fixed solid body, there is a definite relationship between pressure and velocity at any point represented by the equation $p+\frac{1}{2}\rho u^2$ =constant, where ρ is the density of fluid, u is the velocity and p the pressure. Under the influence of a fixed pressure distribution therefore the average variations in p would be equal to the average variation in $\frac{1}{2}\rho u^2$. Stanton pointed out that the variations in p in a natural wind were far less than the variations in $\frac{1}{2}\rho u^2$. On examining his results, however, I found that the average variation in p is in fact equal to the average value of $\frac{1}{2}\rho u'^2$, where u' is the variation in wind velocity from the mean. That is to say, statistically, the variations in velocity in a natural wind correspond exactly with a pressure distribution which travels along with the mean wind.

The next thing I tried was to find out whether there was any relationship between the variations of wind velocity along and across the mean direction of the wind. For this purpose I examined the records of the Dines' anemograph and recording weather vane on Pyestock chimney, 130ft. high. I selected records where the wind appeared to keep a steady mean direction and speed over a period comprising a large number of small gusts or eddies. Drawing two dotted lines on each trace so as to include all but a few extreme gusts as in Fig. 6, I measured two extremes of wind direction and two extremes of wind velocity. Calling the maximum and minimum velocities V_{max} and V_{min} and the angular variation in wind velocity θ, I first calculated the quantity $\frac{V_{max}-V_{min}}{V_{max}+V_{min}}$ which represents the ratio between the variation in wind-velocity from the mean divided by the mean wind. This may be taken as the ratio of the component of eddy motion in the direction of the wind to the mean wind. This I plotted in a diagram (Fig. 7) showing its relationship to $\sin\theta/2$, which represents the ratio of the horizontal component of eddy motion perpendicular to the mean wind. It will be seen that the points lie very nearly on the line drawn at 45 degrees diagonally across the middle of the figure. This means that the horizontal component of eddy motion across the wind is equal statistically to the component along the direction of the mean wind.

On days when the eddy component along the wind was small so also was the component across the wind. It appears therefore that when stratification of density acts so as to reduce turbulence the lateral motion is reduced in the same ratio as the longitudinal motion.

This result seemed so significant that I suspected that one might get a similar result if one could measure the component of eddy velocity in a vertical direction. Accordingly I asked Mr. W. H. Dines to design for me a light wind vane mounted at its centre of gravity by a universal joint so that it would point in the actual direction of motion of the air at any moment. A pen hangs from a point on the arm of the vane and writes on a paper.

Fig. 8 shows a record taken at a height of 25ft. above grassland. It will be seen that the relationship between the vertical and

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the cross-wind velocities is extremely complex, but the fact that the diagram is roughly round shows that the average value of the component of eddy velocity in a vertical direction is equal to the average horizontal component in a direction at right angles to the mean wind.

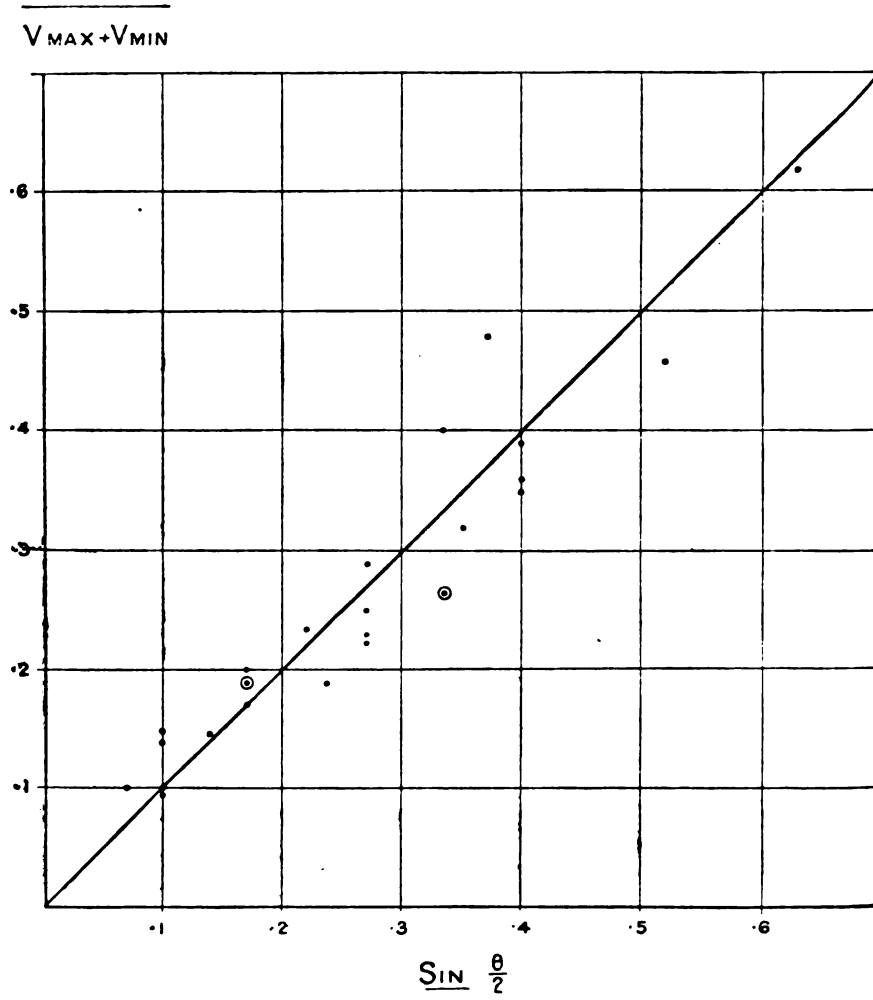

FIG. 7.—Diagram showing that the cross-wind component of eddy motion is statiscally equal to the component along the wind direction.

Fig. 9 shows two records taken at eight feet above a ploughed field and two at 2ft. It will be seen that even at 8ft. the diagram is appreciably flattened so that lateral components tend to be greater than vertical ones. At 2ft. the diagrams are very much flattened.

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This is partly due, no doubt, to the fact that the vane is 6in. from the centre of suspension and this is not small compared with two feet, but it is due chiefly to a real difference between the intensity of eddy components in a horizontal and vertical direction at distances which are not large compared with the sizes of the projections from the ground which produce the eddies.

Before concluding my lecture I should like to draw your attention to one last point in connection with Fig. 9. It will be noticed that the two lower records appear to be tilted slightly in their frames, which were drawn so as to be horizontal and vertical. This tilt means that there was a correlation between the vertical and horizontal components on this occasion so that when the wind was blowing upwards it was on the whole more westerly than when it was blowing downwards. These records were made with a SW wind blowing over furrows which ran east and west. The diagram shows us that the upward currents which had come from the furrows have been deflected along the furrows and that they preserve their direction of motion at any rate up to a height of 2ft. This is the only direct evidence that I have been able to obtain that an upward current preserves the momentum of the layer from which it has come, carrying it into higher layers.

I am sorry that this lecture has been so incomplete, but the enormous amount of ground that I have tried to cover has prevented me from giving adequate attention to any part of the subject and I have been forced to limit myself to a general survey of some outstanding features of turbulent motion.

The Effect of Atmospheric Pressure on the Readings of Thermometers.[1]

It is a well-established fact that the application of a change of pressure to the outside of a liquid-in-glass thermometer gives rise to an immediate change in the position of the liquid in the stem, a recovery to the previous position occurring as soon as the original pressure is restored.

In general, if the change in pressure is uniform over the whole of the glass envelope, then the change in the position of the liquid in the stem bears a constant ratio to the change in pressure, this ratio being known as the external coefficient β. Hence, if p_1 = atmospheric pressure at which the thermometer reads t_1, and t_2 is the indicated temperature at a reduced pressure p_2, then

$$\beta = t_1 - t_2 / p_1 - p_2$$

As considerations of sensitivity of thermometers lead to a reduction in the thickness of the glass, the resulting increase in the external pressure coefficient may become significant in the case of thermometers used on aeroplanes and subjected to large changes of pressure.

This change of position of the liquid with change of pressure can be very easily demonstrated in the case of an aeroplane strut thermometer which has a large flat bulb. If the bulb is pressed a rise can be observed amounting to nearly 1°F.

Doubts were raised by Messrs. Negretti and Zambra as to the correctness of the reading of such a thermometer at high altitudes, and it was

[1] Note prepared in the Instruments Division, Meteorological Office.

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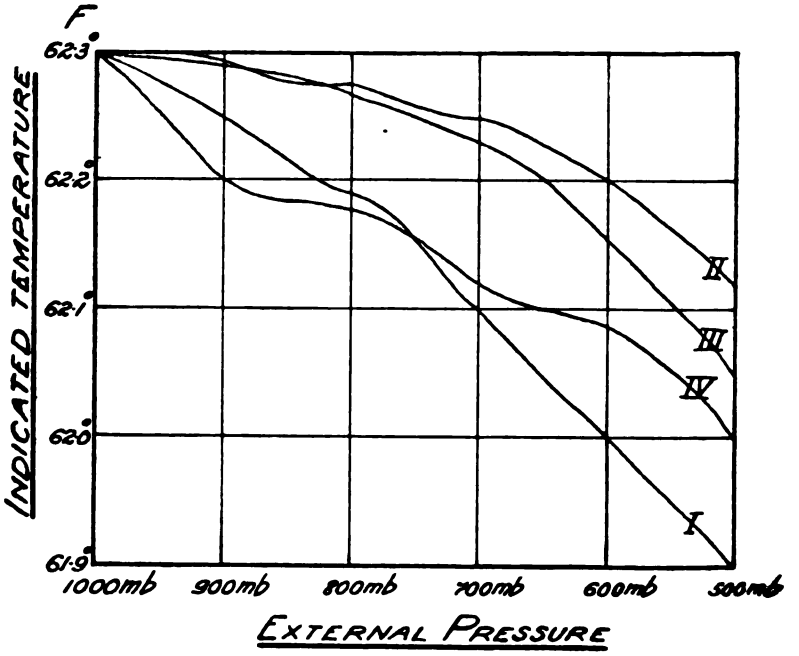

FIG. 1.—Variation of indicated temperature with external pressure.

therefore decided to make tests on thermometers of this and three other types, as follows :—

(1) Ordinary, mercury, Mark II., with spherical bulb, 0.4 inch diameter.
(2) Inspectors, mercury, with spherical bulb, 0.5 inch diameter.
(3) Strut, mercury, with large cylindrical bulb.
(4) Strut, spirit, with large flat bulb.

The thermometers were placed side by side in a vessel, lagged with wool, containing water, the whole being placed in a chamber that could be exhausted. Pressure was then reduced from atmospheric pressure to 500 mb., the thermometers being read at each 50 mb. fall of pressure. When the 500 mb. pressure was reached, the thermometers were left undisturbed for fifteen minutes, after which interval of time the pressure was slowly increased until atmospheric pressure was reached, the thermometers being read at the same intervals of pressure as before.

The results are shown graphically in Fig. 1, the curves being smoothed out. For a change of pressure of 500 mb. the following are the corrections to be applied :

Thermometer (1) +0.4°F.
,, (2) +0.2°F.
,, (3) +0.25°F.
,, (4) +0.3°F.

The inspector's thermometer has the smallest external pressure coefficient, while the Mark II. shows the greatest decrease in temperature. It is not intended to assert that the figures obtained are exactly applicable to other thermometers of similar type, but there seems little reason to doubt that errors due to change of pressure are never likely to be sufficiently large to affect the observations seriously. J. E. BELASCO.

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PAST CLIMATES.

By Dr. G. C. SIMPSON, C.B., F.R.S., F.R. Met. Soc.

[Manuscript received April 28—Read June 15, 1927.]

There has recently been a considerable increase in the interest taken in problems connected with past climates. Wegener's revolutionary theory of the movement of the continents, associated with wandering of the polar axis, has met with serious and strenuous opposition. One of the most important aspects of Wegener's theory is that it gives an explanation of the great changes of climate which geological evidence indicates to have taken place in many parts of the world.[1] This has been a direct challenge to opponents of the theory to produce explanations of these climatic changes on more conservative lines. Variation of solar radiation is the most obvious solution, but there are many patent objections to such an explanation and there seems a reluctance to postulate any but small changes in solar radiation. At any rate this is not a popular solution. Geologists look with much more favour on theories which depend only on changes of the physical state of the earth's surface; changes in the relative extent of sea and land, changes in oceanic currents and changes of elevation, although the latter can only work in the direction of reducing surface temperatures. It seems to be the opinion of many geologists and not a few meteorologists that there is unlimited scope for the control of climate in the re-adjustment of land masses and the introduction of new oceanic currents similar to the Gulf Stream.[2]

Geology offers us three great problems of past climates. In the first place geologists state that there have been long periods when the difference of temperature between equatorial and polar regions was much less than at present. In this period the polar climate is supposed to have been almost sub-tropical, or at the very least that of the Mediterranean to-day.[3] If this were so it would mean that the climatic zone which we now have in latitude 30° or 40° would be drifted polewards between forty and fifty degrees. The second problem is associated with the climate during the last great ice age, when North America down to latitude 40° N. and the greater part of north-west Europe down to about latitude 50° N. were buried under great ice sheets. The third problem is to account for the former existence of ice at sea level within the tropics. We will take these problems in turn.

The existence of a former uniform climate in the northern hemisphere is generally explained by supposing that vast oceanic currents carried warm water to polar regions, either along the course of the present Gulf Stream, or along channels which no longer exist. The Gulf Stream drift now maintains a mean annual temperature off the coast of Norway in latitude 70° N., which is 10°C. higher than the mean temperature of the latitude, and it is supposed that if its volume, velocity or both were increased, and other streams introduced, even higher temperatures could be maintained over the whole of the north polar regions.

This supposition is based on an entirely wrong conception of the physical causes which maintain the existing climatic zones.

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It is impossible in our present state of knowledge to calculate the temperature of the earth's surface from considerations of the solar energy received; but there are some general principles based on observations of existing conditions which enable us to reach important conclusions bearing on this problem. In the first place we know definitely that great quantities of heat are transported from place to place by the general circulation of the atmosphere, warm air being conveyed from equatorial regions to polar regions and cold air being returned in the opposite direction.[4]

In addition, other large quantities of heat are known to be transported by oceanic currents. The transport of heat by oceanic currents is largely a surface effect, and as the surface currents are almost entirely wind driven, the transport of heat by the ocean is in the same direction as the transport by the atmosphere; it is also dependent on the intensity of the general circulation of the atmosphere, for an increased general circulation induces an increased oceanic circulation.

The amount of heat transferred across the various latitudes has been calculated by several methods, and it is found that all latitudes over 35° receive very large quantities of heat which has been extracted directly or indirectly from equatorial regions.[5] Thus the temperature in all high latitudes is higher and in equatorial regions lower than it would be without the general circulation of the atmosphere.

The general circulation of the atmosphere, however, depends for its energy on the difference of temperature between equatorial regions and polar regions. If this difference is large, the general circulation is active; if the difference is small the general circulation is less active. Thus we have two opposing tendencies: (*a*) the temperature difference which induces the general circulation and (*b*) the general circulation, which tends to eliminate the temperature difference. As the present temperature difference has existed unchanged for a very long period, it is obvious that the atmosphere is now in a steady state, in which a balance has been struck between the temperature difference which maintains the general circulation and the amount of the general circulation which transports the heat necessary to maintain the temperature gradient. If through any cause the temperature in high latitudes could be raised, the general circulation of the atmosphere would decrease, less heat would be carried into high latitudes, where the temperature would fall. The temperature would continue to fall until the normal temperature was reached, when the balance would be restored with the original temperature difference, and the original general circulation.

The atmosphere may be compared to a gigantic heat engine in which the general circulation acts as a powerful governor. If the temperature difference between the "boiler" (equatorial region) and the "condenser" (polar region) increases, the engine works faster, transfers more heat from the boiler to the condenser, which in turn reduces the temperature difference again; if the temperature difference decreases, the engine works slower, transferring less heat from the "boiler" to the "condenser," and so the temperature difference is increased again.

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We can apply this reasoning to our problem by considering what would happen if we introduced a second Gulf Stream into the northern hemisphere by, say, cutting a wide channel across the middle of Asia similar to the Atlantic Ocean.

The new Gulf Stream would carry heat into the polar basin, where the temperature would rise. But this rise in temperature would diminish the temperature difference between the equatorial and polar air on which the cyclones of the North Atlantic depend. The winds associated with these cyclones are, however, the chief vehicle for transporting warm air into, and cold air out of, the polar basin; in addition they are the chief factors in driving the present Gulf Stream along its path. Thus the opening of a new supply of heat to the polar regions would be accompanied by a reduction of the old supply, the final result being little or no difference of temperature. The temperature over the polar regions would, however, be more uniform than it is at present, for the warm region over the present Gulf Stream and the cold region in Siberia would both largely disappear.

When we consider that the chief factors which determine the existing temperature difference between equatorial and polar regions are:—

(*a*) The distribution of solar energy at the earth's surface, which depends on the shape of the earth;

(*b*) the loss of heat from the atmosphere by radiation, which depends on the temperature of the upper layers of the atmosphere, and

(*c*) the general circulation of the atmosphere, which depends on the inertia and other physical properties of the atmosphere throughout its whole mass;

we should not expect the temperature gradient between the equator and the poles to depend to any large extent on the distribution of land and sea at the earth's surface. In other words we should expect the average temperature of the zones to be largely independent of the nature of the earth's surface. That this is so, to a surprising extent, is seen when we compare the average temperature along the circles of latitude in the northern and southern hemispheres as they exist to-day.

In Table I. are given the average mean annual temperatures at sea level along various circles of latitude as recently redetermined by Meinardus,[6] and also the proportions of land and sea along each circle of latitude. The values are shown in Fig. 1.

From column four we see that the maximum difference of average temperature of corresponding latitudes is 3°C. and the average difference less than 2°C. The agreement is more surprising when we consider the different conditions in the northern and southern hemispheres.

We will consider first the polar regions. It would be difficult to conceive any distribution of land and sea more different, from the meteorological point of view, than the distribution which exists at present in the two polar regions. Within the Arctic Circle we have a great sea; within the Antarctic Circle we have a great continent. Outside the Arctic Circle we have the continents of North America and Asia forming together the largest mass of land

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in any part of the earth; outside the Antarctic Circle we have a continuous ocean extending completely around the earth for many degrees of latitude. The Gulf Stream, the greatest heat-carrying ocean current which exists, conveys warm water right into the

TABLE I.—MEAN ANNUAL TEMPERATURES AT SEA LEVEL.

Latitude.	Average Mean Annual Temperature.				Percentage of Land.		
	North.	South.	Difference.	Mean.	North.	South.	Difference.
1	2	3	4	5	6	7	8
	°C.	°C.	°C.	°C.	%	%	%
0	26.2	26.2	...	26.2	22	22	...
10	26.7	25.3	1.4	26.0	24	20	4
20	25.3	22.9	2.4	24.1	31	24	7
30	20.4	18.4	2.0	19.4	43	20	23
40	14.1	11.9	2.2	13 0	45	4	41
50	5.8	5.5	0.3	5.6	58	2	56
60	− 1.1	− 4.1	3.0	− 2.6	61	0	61
70	−10.7	−13.3	2.8	−12.0	53	71	−18
80	−18.1	...	...	(−18.1)	20	100	−80
90	−22.7	...	...	(−22.7)	0	100	−100
0-90	15.2	13.3	1.9	14.2	39	17	22

heart of the Arctic Ocean; in the south no warm current carries warm water within 40° of the pole. Taking latitude 70° as being typical of the polar region we see from Table I. that the average temperature along latitude 70° N. is −10°.7C. and along 70° S. it

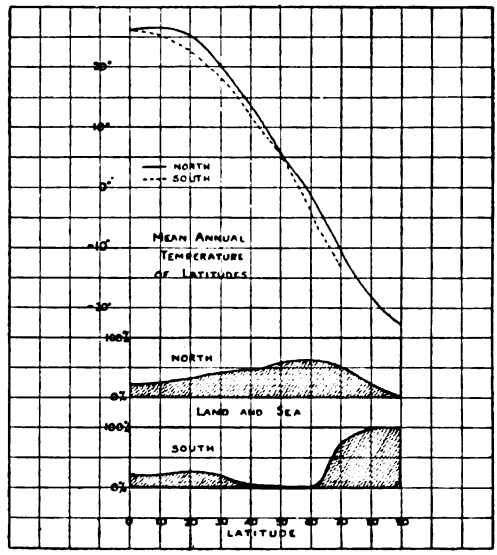

FIG. 1.

is −13°.3C.; a difference of only 2°.8C. in spite of the vast difference of the physical conditions in the two regions.

Let us turn now to what for convenience may be called the temperate regions, between latitudes 40° and 60°. Again, it would

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be impossible to conceive a greater difference between the physical features of the two regions. Between 40° S. and 60° S. there is practically no land; wind, oceanic currents and temperature, both sea and land, are nearly symmetrical about the pole. Between 40° N. and 60° N. more than half the area is covered by land, the distribution of which breaks up the earth's surface into two great land masses and two great oceans. There are vast differences in wind, temperature and oceanic currents along the zone so that there is no symmetry at all; yet the mean difference of temperature between the zones in the south and in the north is only 1°.4C. The fall of temperature polewards between latitudes 40° and 60° is 15°.2C. in the southern hemisphere and 16°.0C. in the southern hemisphere; that is, a fall of 0°.8C. per degree of latitude; therefore the difference of 1°.4C. between the temperatures in the north and south temperate zones is equivalent to a shift of the zone by only 2° of latitude.

From this survey we see that the average temperature of a zone on the earth's surface is practically independent of the distribution of land and sea, and that the great difference in land masses, oceans and oceanic currents which exists between the northern and southern hemispheres has no appreciable effect on the zonal temperatures. We have also seen that high latitudes are warmer and low latitudes cooler than they would be in the absence of the general circulation of the atmosphere and that the general circulation of the atmosphere acts as a natural governor preventing any material departure from the existing zonal temperatures. The temperature difference between high and low latitudes is thus characteristic of the physical properties of the atmosphere, and therefore, so long as these have been the same, there must always have been temperature zones similar to those which exist to-day.

Although the distribution of land and water plays a very small part in determining the average temperature of a zone, it plays a very large part in determining the actual temperature in various parts of the zone.

The reason for this is easily seen. Just as the initial difference of temperature between polar and equatorial regions due to solar radiation gives rise to the general circulation of the atmosphere, which in its turn brings about the final and steady distribution of temperature; so the unequal temperature over land and water in the same zone sets up local circulations which tend to remove these secondary differences of temperature. Again, we can do little by calculation and must turn to observations to determine the magnitude of this effect.

Fig. 2 has been reproduced by the kind permission of Prof. Süring from Hann's *Lehrbuch der Meteorologie* to show the existing variations of mean annual temperature. We see at once that the temperature may be very different at different places along the same circle of latitude. The greatest differences occur along latitude 70° N., the mean temperature off the coast of Norway being more than 20°C. higher than the mean temperature in the west of Siberia. The temperature distribution of this high latitude is very complicated owing to the irregular distribution of land and the presence of ice. We can best investigate

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the effect of the distribution of land and water by studying the conditions in the zone 40° N. to 60° N. where there is no ice and the land and sea are more simply distributed.

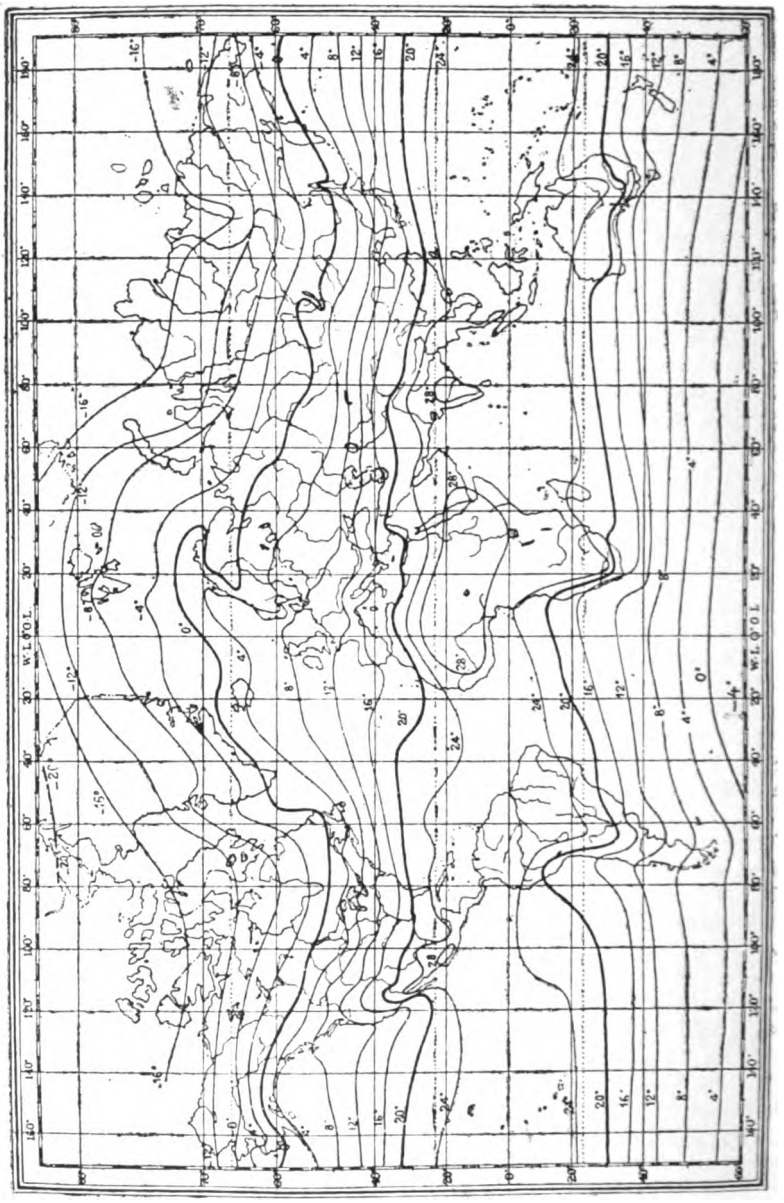

Fig. 2. Yearly Isotherms.

From Fig. 2 we at once notice that in the zone between 40° N. and 60° N., the temperature is highest over the east of the oceans and lowest over the east of the continents. This is due almost entirely to the fact that over the east of the oceans the

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prevailing winds have a southerly component and over the east of the continents a northerly component. This means that the chief transport of warm air from equatorial regions is over the east of the oceans, and as the winds control the movements of the surface waters the effect of the ocean currents is simply an addition to the effect of the winds. On the other hand, the return flow of air from polar regions is mainly over the east of the continents, bringing with it low temperatures from higher latitudes. Whatever the distribution of land and sea within the zone we may expect the same effect, the transport of warm air will be over the east of the waters and the transport of cold air over the east of the land masses. The only question that arises is whether there are any limits to the difference of temperature that may be induced in this way. The areas of the continents and of the oceans in the zone we are A glance at Fig. 2 will show that there appear to be such limits. considering are very different, the extent of Asia being more than twice that of North America and the extent of the North Pacific Ocean being more than twice the extent of the North Atlantic. In spite of this difference of extent the lowest temperature on any latitude over North America is almost exactly the same as the lowest temperature on the same latitudes over Asia. In the same way, in spite of the Gulf Stream the highest temperatures over the North Pacific are very similar to those over the North Atlantic.[1] This is shown in Table II.

TABLE II.

Latitude.	Lowest Mean Annual Temperature.			Highest Mean Annual Temperature.		
	America.	Asia.	Difference.	Atlantic.	Pacific.	Difference.
°N.	°C.	°C.	°C.	°C.	°C.	°C.
40	10	10	0	17	14	3
45	6	4	2	14	12	2
50	1	0	1	12	9	3
55	− 5	− 4	−1	9	7	2
60	− 8	−18	0	8	5	3

The figures are the most striking in the case of the low temperatures in the east of the continents (see Fig. 3). From latitude 40° N. to 60° N. the great Asiatic land mass produces the same lowering of the temperature as is produced by the much smaller North American continent. From this we may conclude that North America is already sufficiently extensive to produce the maximum cooling and that no readjustment of the land masses within this zone would produce lower mean annual temperatures than exist to-day in the east of North America and in the east of Asia.

Similarly over the sea; when we find that the highest temperatures over the broad North Pacific Ocean are within three degrees of the corresponding temperatures in the narrow North Atlantic with its active Gulf Stream, we may legitimately draw the conclusion that no redistribution of land and water would materially raise the temperature over the sea.

We thus see that in the north temperate zone there are quite

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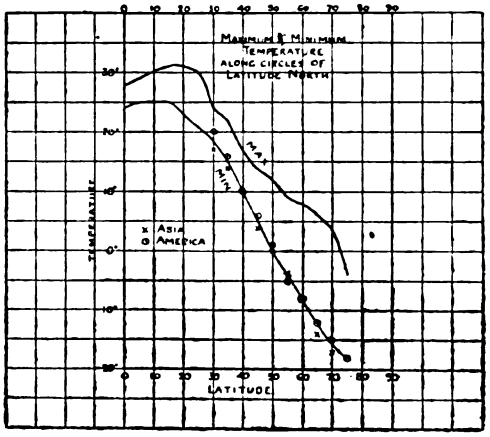

Fig. 8.

definite maximum variations from the mean temperature of the circles of latitude and that these exist to-day over both North America and Asia. The conclusion is irresistible that at no time in the past could mean annual temperatures exist locally in the north temperate zone which do not occur on the same latitude to-day.

We will now consider the conditions in Polar regions. As already stated the Gulf Stream, the irregular distribution of land and sea, and the presence of ice in north polar regions complicate the problem and we cannot therefore attribute the irregularities simply to land and water as we have done in lower latitudes. We are therefore forced to make use of the fact which we have already discussed that the average temperature along a circle of latitude is fixed by other considerations.

If it is true that local conditions only cause irregularities in the average temperature along a given latitude, any large variation must be compensated by other variations in the opposite direction. In latitude 70° N. the Gulf Stream produces a large local abnormality in temperature and this is compensated by the cold regions in North America and North Asia.

With another distribution of land and water and other oceanic currents we should have the same average temperature. To get greater variations of temperature than now exist we should therefore have to provide a stronger Gulf Stream—I have already shown that to provide another Gulf Stream would only reduce the present abnormality. An intensified Gulf Stream is conceivable but it is very unlikely, for it would itself tend to destroy the conditions which give rise to it. The extremely favourable conditions for the development of a warm current which now exist in the configuration of the basin of the North Atlantic—a long trough tending in the direction of the prevailing winds—would be difficult to improve and as the heat is carried almost entirely by the surface wind-driven layers so that the depth is of secondary importance the only obvious improvement would be to remove Iceland. That more favourable conditions ever existed in the past is very doubtful; therefore, in all probability we have at present in North Polar

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regions temperature abnormalities as great as have ever existed in either polar region at any time. This leads us to the same conclusion as we reached for the lower zone, and we may combine the two results by saying that at no time in the past is even a limited region of the earth's surface north of latitude 40° likely to have had a higher or lower mean annual temperature than can be found somewhere on the same latitude to-day. The same limits of temperature would obviously apply to the southern hemisphere also.

So far I have dealt with mean annual temperature only. To examine the extremes of temperature which may occur in the summer and winter in the various latitudes would make this paper too long; but in my opinion the same conclusion would be reached, namely, that the variations found to-day in the northern hemisphere are never likely to have been exceeded in either hemisphere at any time in the past.

We now come to the second problem. Can the great ice age have been caused by geographical change, that is by increasing the amount of land or by raising its surface? We have already seen that the readjustment of the land even if it caused considerable changes in the oceanic currents would not alter the mean temperature of the zone. Therefore we must look to changes which would produce locally the conditions favourable to the formation of ice.

We will limit our discussion to the conditions in north-west Europe during the great ice age when a sheet of ice covered the whole of Scandinavia and extended over the Baltic and North Seas and spread over the British Isles north of the Thames, and over Holland, Denmark, North Germany and the greater part of Russia in Europe. It is important to notice that this was a sheet of what is called inland ice, that is, it was an unbroken sheet and not simply the ends of glaciers which descended in isolated streams from high land. It has been suggested that Scandinavia was then a high land which became glaciated; the sheet is supposed to have formed first on this high land and then to have gradually spread over the surrounding low lands, the development being favoured by the meteorological conditions induced by the growing ice sheet itself. Considerable light is thrown on this problem by considering the present conditions in Greenland. Here we have a large area almost entirely covered by a sheet of inland ice. Practically the whole of its surface is more than 1,000 metres above sea level and locally it reaches 3,000 metres. Its southern point is in latitude 60° N. and its northern coast extends beyond 80° N.; yet nowhere does its inland ice sheet extend right down to sea level. De Quervain[8] states that the edge of the inland ice on the west coast in latitude 70° N. is at a height of 1,450-1,500 metres while on the east side in latitude 66° it is at a height of 820 metres. The snow-line is of course still higher. The conditions for the extension of an inland ice sheet could hardly be better than they are in Greenland. As is well known the height of the snow-line and the extent of a glacier depends largely on the summer temperature, the depth of cold in the winter has little effect. A low summer temperature is therefore favourable for the extension of an ice sheet. The conditions are almost ideal for producing a low summer temperature on the coast of Greenland; for both its east and west coasts are

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bathed by cold oceanic currents. It is almost impossible to reach the east coast even in the middle of the summer on account of the ice carried along its shores, while along the west coast the summer temperature is lower than anywhere else along the same latitude. In spite of all this the ice sheet fails to cover the whole of the land, but ends at a height of about a thousand feet, leaving all the low lying land near the coast free of permanent ice.

Now imagine Greenland lifted bodily and placed over Scandinavia, so that its southern point is in northern Germany and its north coast somewhat north of the present North Cape. It would then provide the kind of high land, both in extent and height, which is generally invoked to explain the ice age.

But how different would then be the conditions to which the edges of its ice sheet would be subjected. Its west coast instead of being bathed by a cold sea would be subjected to the warm waters of the Gulf Stream and the mean summer temperature would be 12°C. instead of 6°C. The conditions in its eastern side would be much worse, for instead of being protected by an ice-bearing current, it would be subjected to the hot summer conditions of a large continent. Its eastern edge would be in the neighbourhood of Berlin, Leningrad and Archangel, the mean summer temperatures of which are 18°C., 17°C. and 14°C. If the ice sheet cannot survive summer temperatures in the neighbourhood of 6°C. how could it survive temperatures of this kind?

It is true that the Scandinavian high land would receive more precipitation than Greenland receives now; but the increase would not be large, for the very meteorological conditions which would be necessary to maintain the ice sheet—a glacial anticyclone—would prevent appreciable precipitation. It may be mentioned that there are now isolated sheets of inland ice in Norway, but they do not extend even to the edges of the plateaux on which they form.[9] Also in Iceland, where there are large ice fields and much precipitation, even the glaciers do not extend to sea level.[10]

When all allowance is made for increased precipitation it is impossible to believe that the Greenland ice sheet, which cannot in its present favourable position extend to sea level, would after transportation ten degrees further south grow to such large dimensions that it would not only descend to sea level but would extend over large areas of flat low ground, where on one side it would be subjected to the warm waters of the Gulf Stream and on the other to a hot dry continent. Of course, other changes might be postulated, for example, the complete diversion of the Gulf Stream, but whatever changes of this nature are considered, the fact remains that the mean temperature of the zone would remain what it is to-day, and the summer temperatures over the centre of Europe would be relatively high. It is of course difficult to *prove* what would happen; but there is nothing now in existence in the world to make one believe that an ice sheet could exist in such conditions; on the other hand, the present conditions in Greenland appear to me to be overwhelming evidence that the ice sheet could not exist.

From the above considerations I feel justified in concluding that the ice age in Europe would not have been brought about by mere physical changes of the earth's surface.

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We will now consider the last of the problems which I set out to investigate. Can ice at sea level within the tropics be brought about by any rearrangement of the land and sea masses?

The evidence of ice action at or near sea level within the tropics is best seen by a scratched pavement near Chanda (latitude 20° N.) in the Central Provinces, India.[11] The evidence that the ice sheet which caused these scratches was near sea level is fairly conclusive and is generally accepted by geologists. The evidence is also strong that the scratches were not made by an isolated glacier, but by a true inland ice sheet. We will, however, examine the possibility of glaciers having extended at some time to sea level in this position for if glaciers could not reach sea level there is no possibility of inland ice having done so.

Some ten degrees of latitude north of Chanda is the great Himalayan range of mountains rising far above the snow-line which is here about 5,000 metres above sea level. In this range there are large glaciers; but none of them descends within 3,000 metres of sea level.[12] The question is whether any change of climate could take place which would bring these or similar glaciers down to sea level. The normal fall of temperature with height is 6°C. per 1,000 metres, thus a fall of temperature of more than 18°C. would be necessary if temperature were the only factor. The present mean temperature at the foot of the Himalayas is 20°C., so that a mean temperature well under 2°C. would be necessary to bring the glaciers down to sea level.

Increased snowfall would result in longer glaciers; but it is difficult to conceive any conditions more favourable for snowfall than those which now exist in the Himalayas. These great mountains rise as a barrier across the path of the moisture-bearing monsoon winds; in their foot hills are some of the wettest regions on the earth; therefore it is unlikely that any other land sufficiently high to reach above the snow-line could be found to collect more snow. Increased precipitation therefore seems to be ruled out and the only solution would appear to lie in the direction of decreased temperature.

The decreased temperature might be general over the whole equatorial regions or it might be only local. As to a general fall in temperature we have already seen that this is impossible; the temperature of the zone is fixed so long as solar radiation and the constitution of the atmosphere remain unchanged. The only possibility is therefore that by a redistribution of land and water the mean annual temperature might be reduced locally by the required amount. North and south of latitude 35° where the atmosphere receives heat transported from equatorial regions the lowest mean temperatures are found over the land and the highest over the sea. Within the equatorial belt the conditions are reversed as a glance at Fig. 2 will show. Here the land masses are relatively warm and the sea relatively cool. The coldest spot in the tropics at present is in the South Pacific, just off the coast of Chile, where the mean temperature is 18°C. This abnormally low temperature is due to a well-developed cold ocean current which is deflected from latitude 56° S. along the coast of South America. It is difficult to conceive more favourable conditions for a low tempera-

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ture within the tropics; yet this is still 16°C. above the maximum temperature which we have deduced to be allowable if the glaciers of the Himalayas are to extend to sea level. On the coast of Chile there are the lofty Andes and it is interesting to note that the height of the snow line is here between 5,000 and 6,000 metres above sea level;[13] there are no glaciers in this position. Thus we have in the same latitude as Chanda a lofty range of mountains the foot of which is washed by a cold oceanic current so that the temperature is reduced to the lowest point of any region within the tropics, yet the snow-line is still more than 5,000 metres above sea level.

We see in this way the impossibility of accounting for ice at sea level within the tropics by any conceivable rearrangement of the physical features of the earth's surface. Thus we fail to find a solution to the third problem satisfactory to meteorological science.

Conclusions.

This discussion was undertaken to see whether meteorology could set limits to the changes in climate which are possible as the result of changes in the physical condition of the earth's surface, mainly, changes in the extent and distribution of land masses. We have seen that the zonal distribution of temperature cannot be changed, so that there must always have been a cold polar zone, a warm tropical zone and an intermediate temperate zone, all very similar to those which exist to-day. We have also examined the variations in mean annual temperature at different locations in the temperate and polar zones and found good reasons for believing that no rearrangement of land and water could have produced larger variations in temperature than are to be found in the northern hemisphere to-day.

An examination of the extent of the ice sheet covering Greenland which does not descend to sea level in spite of the favourable geographical and meteorological conditions to which it is exposed, led to the conclusion that an ice sheet could not have extended from high land in Scandinavia to cover the area which was ice covered during the last ice age.

Finally a discussion of the present conditions in tropical regions, where in the coldest place the snow-line is more than 5,000 metres above sea level, led to the conclusion that ice could never have reached sea level within the tropics.

We thus see that meteorology is unable to offer a solution of the three main problems of past climates. The evidence that the climates described by the geologists did occur in the regions specified cannot be controverted. It is not the business of a meteorologist to say how these contradictory conclusions can be reconciled; but a consideration of them led an eminent meteorologist to point a way out;[1] it is for the geologists to say whether this solution is the true one.

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DISCUSSION.

Sir T. W. EDGEWORTH DAVID said: Geologists should surely be grateful to Dr. G. C. Simpson for this paper, which indicates the inadequacy of changes in the distribution of land and water or changes in the height of the land in the past, to explain those mysterious former changes of climate known as Ice Ages, as well as changes from former warm climates to modern cold ones.

In regard to the incompetency of changes in the distribution in land and sea to account for such climatic changes, a point of great interest stressed by Dr. Simpson is the control by the temperature gradient in the ocean, of the transfer of heat from the Equator to the Poles. Obviously, the steeper the gradient the more rapidly will the warm currents flow, and the more quickly, therefore, will they transport heat from the Equator to the Poles; but if the volume of the currents be increased, Dr. Simpson shows that temperature at the Poles will be increased only momentarily; for as soon as the ocean temperatures at the Poles rise, the heat gradient is lessened in the oceans between the Equator and the Poles, and so the warm currents are slowed down, and practically only the same amount of heat as before is now carried by the slower moving but larger current, as was conveyed before by the smaller but more rapidly moving current.

Next, in regard to Ice Ages, Dr. Simpson has emphasised the immense change of climate needed to bring an ice sheet down to near sea level at Chanda in the Central Provinces of India, that area having been covered by a vast ice sheet in Permo-Carboniferous time. He (Sir Edgeworth) had seen the wonderful evidences of that old ice sheet, which, moving from lat. 18°N. across Rajputana to the Salt Range in lat. 32°N., dumped its erratics into the marine sediments of the Salt Range area. Dr. Simpson estimates that a fall of temperature of not less than 12°C. would be necessary now to bring down the Himalayan Glaciers, in the form of an ice sheet, to near sea level north of the latitude of Chanda (20°N.), but he had since calculated that a fall of about 18°C. would be necessary.

In my opinion the Permo-Carboniferous Ice Age was consequential

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ture within the tropics; yet this is still 16°C. above the maximum temperature which we have deduced to be allowable if the glaciers of the Himalayas are to extend to sea level. On the coast of Chile there are the lofty Andes and it is interesting to note that the height of the snow line is here between 5,000 and 6,000 metres above sea level;[13] there are no glaciers in this position. Thus we have in the same latitude as Chanda a lofty range of mountains the foot of which is washed by a cold oceanic current so that the temperature is reduced to the lowest point of any region within the tropics, yet the snow-line is still more than 5,000 metres above sea level.

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We thus see that meteorology is unable to offer a solution of the three main problems of past climates. The evidence that the climates described by the geologists did occur in the regions specified cannot be controverted. It is not the business of a meteorologist to say how these contradictory conclusions can be reconciled; but a consideration of them led an eminent meteorologist to point a way out;[1] it is for the geologists to say whether this solution is the true one.

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4. Defant: *Geografiska Annaler,* Heft 3, 1921, p. 209.
   Defant: *Met. Zeit.,* **39,** 1922, pp. 8-14.
   Mügge: *Zeitschrift für Geophysik,* **2,** 1925, p. 63.
   Ångström: *Beitr. zur Geophysik,* **15,** 1926, pp. 1-13.
   Exner: *Met. Zeit.,* **44,** 1927, pp. 46-53.
5. Mügge: *Loc. cit.* (4).
6. Meinardus: *Nachr. der Gesell. der Wiss. zu Göttingen,* July, 1925; also Hann, *Lehrbuch der Meteorologie,* 4th ed., p. 848.
7. TABLE II. has been prepared from the chart of Annual Isotherms compiled by Hann and published in Berghaus' *Atlas der Meteorologie.* Fig. 1 is based on the same chart.
8. De Quervain: *Erg. der Schweiz. Grönland expedition,* 1912-13, p. 150.
9. Hess: *Die Gletscher.* Brunswick, 1904, p. 89.
10. Hess: *Loc. cit.* (9), p. 93.
11. (*a*) *Geology of India,* 2nd ed., Melicott, Blanford and Oldham.
    (*b*) *Record of the Geological Survey of India,* **8,** part 1, 1875, pp. 16-18.
    (*c*) *Memoirs of the Geological Survey of India,* **13,** part 1, pp. 16-18.
12. Hess: *Loc. cit.* (9), p. 94.
13. Paschinger: *Petermanns Mitt.,* Erg. Heft 173, 1912, pp. 41-42, pl. 2.

DISCUSSION.

Sir T. W. EDGEWORTH DAVID said: Geologists should surely be grateful to Dr. G. C. Simpson for this paper, which indicates the inadequacy of changes in the distribution of land and water or changes in the height of the land in the past, to explain those mysterious former changes of climate known as Ice Ages, as well as changes from former warm climates to modern cold ones.

In regard to the incompetency of changes in the distribution in land and sea to account for such climatic changes, a point of great interest stressed by Dr. Simpson is the control by the temperature gradient in the ocean, of the transfer of heat from the Equator to the Poles. Obviously, the steeper the gradient the more rapidly will the warm currents flow, and the more quickly, therefore, will they transport heat from the Equator to the Poles; but if the volume of the currents be increased, Dr. Simpson shows that temperature at the Poles will be increased only momentarily; for as soon as the ocean temperatures at the Poles rise, the heat gradient is lessened in the oceans between the Equator and the Poles, and so the warm currents are slowed down, and practically only the same amount of heat as before is now carried by the slower moving but larger current, as was conveyed before by the smaller but more rapidly moving current.

Next, in regard to Ice Ages, Dr. Simpson has emphasised the immense change of climate needed to bring an ice sheet down to near sea level at Chanda in the Central Provinces of India, that area having been covered by a vast ice sheet in Permo-Carboniferous time. He (Sir Edgeworth) had seen the wonderful evidences of that old ice sheet, which, moving from lat. 18°N. across Rajputana to the Salt Range in lat. 32°N., dumped its erratics into the marine sediments of the Salt Range area. Dr. Simpson estimates that a fall of temperature of not less than 12°C. would be necessary now to bring down the Himalayan Glaciers, in the form of an ice sheet, to near sea level north of the latitude of Chanda (20°N.), but he had since calculated that a fall of about 18°C. would be necessary.

In my opinion the Permo-Carboniferous Ice Age was consequential

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on a world-wide fall of temperature, and was mostly independent of elevation of the land, and was controlled only to a minor extent by changes in the distribution of sea and land at that epoch as compared with the present. The almost total extermination of the warm-water-loving reef-forming corals in the stupendous glacial epoch, of late Carboniferous to early Permian time, demands a general refrigeration of the whole globe (probably due to some extra-terrestrial cause) in order to explain the fact that over 90 per cent. of the species of animal life in the Upper Carboniferous seas perished with the advent of Permian time.

In regard to Wegener's explanation of the Ice Ages through continents drifting like icebergs, and thus shifting the position of the Poles, Dr. J. W. Evans has stressed the fact that continents can move considerably in the course of many millions of years, as has been demonstrated by Argand and Staub. Staub, in his *Bau der Alpen,* shows that the Swiss Alps have developed as the result of a push over from the south of no less than 1,000 miles, so that what was, some fifty millions of years ago, North Africa, is now sitting down on the Swiss Alps. But it has always seemed to me that apparently a fatal objection both to this and to the geographical hypothesis is the shortness of the geological time within which all the great climatic changes of the last great Ice Age, the Pleistocene, took place. If we accept the view that in Pleistocene time there were at least four great ice epochs (known in Switzerland as the "Gunz," the "Mindel," the "Riss" and the "Würm") separated from one another by three interglacial epochs (the present day being perhaps another interglacial epoch), and also accept the amply demonstrated conclusion of Penck, A. P. Coleman and others, that these eight great climatic changes have all taken place within one million years, or half a million years of to-day, there is obviously not time for secular continental drift, nor for geographical change to bring about such rapidly recurring and intensive climatic changes. Dr. Simpson's paper should be welcomed as eliminating the possibility of change in height of land or change in distribution of sea and land having been dominant factors in bringing about Ice Ages, or other great changes of climate. Such geographical changes have surely acted as fine adjustments of the climatic microscope, but the cause of the coarse adjustments is yet to seek.

Dr. C. E. P. Brooks said that he proposed to confine his attention mainly to Dr. Simpson's first problem, namely, the warm polar climates, for which there was abundant geological evidence. Dr. Simpson argues that if a second ocean current similar to the Gulf Stream Drift entered the Arctic Ocean, the result would be that each current would have only half the strength of the present Gulf Stream Drift, and the mean temperature of the Arctic would be the same as at present. The reasoning is purely qualitative, but this is not enough; it is necessary to treat the problem quantitatively. Let T be the equatorial temperature which we may regard as constant and t the polar temperature, and suppose that the strength of the atmospheric circulation C is proportional to $T-t$, or choosing suitable units, $C=T-t$. Further, let W be the width of the channels leading to the Arctic Ocean, and let the total heat supply to the Arctic be proportional to CW, or again choosing suitable units, let $t=a+CW$. Dr. Simpson's argument comes to this, that however W varies, t, and therefore $T-t$, remains constant, because if W increases,

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C decreases proportionally. If we replace C by $T-t$, this means that t has to increase in order to remain constant. Obviously, then, the addition of a second Gulf Stream Drift must increase polar temperatures.

There is another point. Dr. Simpson compares the atmosphere with a heat engine in which the polar regions act as condenser. The temperature of a condenser depends not only on the heat which is put into it, but also on the method of cooling. At present the condenser is very efficiently ice-cooled, large surfaces of ice having a remarkable capacity for getting rid of heat by reflection to space, but all geologists are agreed that for large parts of geological time the condenser was water-cooled, an inefficient method which allows quite a weak circulation to maintain high polar temperatures. The main argument of his (Brooks's) book was, in fact, that the difference between a world in which the polar regions are glaciated and one in which they are free of ice far transcends anything which can be attributed directly to the local distribution of land and sea. Such a difference would easily account for the temperate floras which, for example, surrounded the North Pole in high latitudes in the Upper Eocene. An increase of 3°C. in the mean annual temperature, such as Dr. Simpson found to occur between the two hemispheres in latitude 60°, would amply suffice to effect such a change from glacial to non-glacial.

The result shown in Table II. is just what one would expect from his work on continentality, in which it is shown that land more distant than 20 degrees of arc, or, say, 1,500 miles, has very little effect on temperature. It does not follow that in a non-glacial world the temperature on the eastern margins of the continents would not be very much higher.

With regard to Dr. Simpson's second problem, he would only remark that there is very strong evidence, almost amounting to certainty, of contemporary glaciation in Europe, Asia, Australasia, North America and South America. There is other evidence that the quantity of ice in the Quaternary was very much greater than at present, in the presence of coral reefs, which Daly has shown were due to the gradual return to the oceans of a depth of 200 feet of water at one time locked up in the ice sheets.

With regard to Dr. Simpson's third problem, the Upper Carboniferous Ice Age, he would only remind Fellows that not only is it possible to conceive of conditions more favourable for tropical glaciation than those which now exist in the Himalayas, but that about two years ago he presented such a conception, and showed that it was actually realised during the Carboniferous period.

Dr. J. W. Evans thought that Dr. Simpson had proved his case and shown that no change in the configuration of land and sea would account for the great climatic changes that were known to have occurred.

It had been suggested that the glacial period might have been due to the elevation of portions of the earth's surface, and Scandinavia was mentioned in this connection; but there was no evidence of the elevation of Scandinavia in Mesozoic or Kainozoic times. The present rise of that peninsula only commenced when the glaciation was diminishing. The Alps, Pyrenees and other lofty mountain ranges were probably at their highest a considerable time before the glacial period. There was, it is true, in the south of England an extensive rise in late Pliocene or early Pleistocene times which brought the marine Lenham Beds high

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above the seas; but it could hardly be contended that this caused all northern Europe to be covered by an ice sheet.

The problem of the major changes of climate still remained to be solved.

The shifting of the earth's crust (as a whole), bringing different areas in turn under the Poles, seemed at first sight very promising. If the north of the Atlantic were thus brought under the North Pole, most of the widespread glacial phenomena of North America and Europe would be explained, as well as the fact that there seems to have been no extensive glaciation in Eastern Asia. Unfortunately, however, Patagonia seemed to have been simultaneously subjected to severe glaciation, though it should on this hypothesis have then been further from the South Pole than at present.

Variation in the solar radiation is a possible explanation, but it is still purely hypothetical.

The uniformity of climate that seems to have prevailed in early Palæozoic times may be accounted for by the former presence of considerable amounts of interplanetary material, the residue of which now gives us the Zodiacal Light. This had also been employed by Dr. Jeffreys to explain the nearly circular orbits of the planets, which were originally (there was reason to believe) highly elliptical.

It was formerly customary to explain the deviations of the average daily temperature at certain dates from a true annual sine curve by supposing that at such dates the earth was passing through the nodes of orbits of swarms of meteoric matter between it and the sun. If this were verified by observation of the "Solar Constant," a reasonable explanation of a great cold period would be provided by supposing that at that time the plane of the earth's orbit coincided with that of an interior swarm of meteoric matter.

Every theory adduced to explain the great climatic changes was a wide "extrapolation" from facts still imperfectly known, and until we had further information, and data extending over a longer period, it would be impossible to decide which represented the truth.

Sir NAPIER SHAW said that, for the most part, the theories which meteorologists might make had to face comparison with the facts within a short time, sometimes even to-morrow, and in consequence they had not the unfettered liberty of hypothesis which geologists enjoyed. In his interesting paper Dr. Simpson had entered upon the difficult task of proving a negative, of showing that what can be classed as ordinary natural agencies could not account for sub-tropical fossils in Greenland, the last great Ice Age or the marks of ice on Indian rocks. Attempts in the past to prove negatives about the forces of nature had sometimes been unfortunate. Explaining that he preferred a method which proceeds by computation of the extent of the influence of ascertained causes of disturbance, Sir Napier excused himself from dealing with the last of the three questions.

He remarked that Dr. Simpson had used the mean temperatures of the year along circles of latitude in the earth's present condition as his criterion and had shown that in that respect at the present time the northern and southern hemispheres were nearly identical. The problem of fossils in Greenland was, however, a biological one. The most conspicuous feature of difference between the two hemispheres was not their mean temperatures, but the great difference in seasonal variation and in

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annual range as shown in diagrams exhibited in the Meteorological Office. It was for biologists to say how far that feature affected vegetable and animal life for a given mean annual temperature. It could not be assumed to be negligible.

Further, though orographic features had been mentioned by Dr. Evans, no stress had been laid upon them by Dr. Simpson. Yet the climatic conditions of the globe depended not merely on the area of land in comparison with water or its distribution, but also on its altitude. The influence might be of vital importance.

He was under the impression that one of the accepted principles of geology was that the levels of all countries changed in the course of millions of years: that if there were fossils in rocks, the rocks must have gone down into the sea to get them. If it were true that our chalk cliffs were composed of material deposited in deep water, it was not fair to judge of the condition of past ages by present contours. Levels were constantly changing over vast areas and thickness.

The Alps were reported to be a recent creation and the Himalaya too. What would the polar climate be like if Greenland were under water collecting fossils and there were no Alps or Himalaya—if, in fact, the earth were flat and generally submerged? Could the conditions of the Antarctic ice sheet be reproduced in the northern hemisphere?

He offered at the moment no answers to these questions, but expressed the hope that any biologist, geologist or meteorologist who had adopted what he had called natural causes as his working hypothesis, while always bearing in mind Dr. Simpson's conclusions, would not be deterred from pursuing his investigations. There was no place for an Athanasian creed in meteorological science. A working hypothesis that stimulated mental activity was worth pursuing, even if it were not orthodox and turned out in the end to be insufficient to carry the load for which it was designed. Pursued with honest purpose it would certainly lead to a useful increase of natural knowledge.

In communicating a report of his remarks Sir Napier adds that the subject was originally brought to his notice by the late Mr. F. W. Harmer, who was seeking an explanation of the great deposit of shells in the red crag or coral rag of Norfolk, and thought that it must imply a prevailing easterly wind on the East Coast. The question of the possibility of a prevailing east wind in that region through geological changes under uniformitarian conditions seemed to him to be worth pursuing because a full answer must lead to a real comprehension of the atmospheric circulation.

In working out the problem he would attach great importance to the steam of the atmospheric engine. He thought that the influence of water vapour might be regarded as something greater than that of the travel of warm air.

Mr. L. C. W. BONACINA said there was nothing in the present climatic status of the Himalayas, or the tropical Andes, that could be regarded as analogous to the hypothetical cold monsoon conditions which Brooks had postulated for Gondwanaland, both in a previous paper to this Society and in his recent book *Climate through the Ages*. There it is clearly shown under what conditions a tropical snowline down to 6,000 feet is possible or conceivable. Dr. Simpson had attacked this on the ground that the said Gondwanaland would be under desert conditions, but he (Mr. Bonacina) had pointed out[1] that desert conditions in

[1] *Q.J.R.Meteor.Soc.*, Vol. **52**, 1926, p. 261.

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equatorial, as distinct from tropical, latitudes could only occur if the "planetary" equatorial rain-belt as dependent on convergent winds were locally subverted.

Dr. Simpson's analogy from Greenland was admittedly more serious in relation to the Pleistocene Ice Age, but an initial ice sheet with a sufficiently wide periphery would apparently be able to extend itself down to sea level.

Finally, Mr. Bonacina would like to recall the fact that in 1924, in circumstances which Dr. Simpson will remember, he had in endeavouring to interpret Spitaler's continentality map been compelled to do some very severe thinking, the outcome of which left him no escape from the following conclusion: *without differentiation of the earth's surface, weather in anything like the form we know it would cease to exist.*[2] On a uniform globe Equatorial and Polar winds would so quickly readjust their temperatures to change of latitude that the Polar Front itself would lose its sharpness. Now if this conclusion is sound—and nothing in the lapse of four years had shown it to be fallacious—does it not follow, as a logical step, that if geographical differentiations manufacture weather, any change in geographical distributions must affect average weather—in other words, climate—exactly in accordance with Dr. Brooks's actual demonstration?

Dr. JEFFREYS, in a written communication, said that the fact that the present differences of temperature, attributable to geographical conditions, amount to only a few degrees was fully brought out in Brooks's earlier papers on *Continentality and Temperature.* Since that time Brooks had shown that a change of only a few degrees was enough to make all the difference between a polar ocean quite free from ice and one completely choked by ice all the year round, and had made out a strong case for the belief that the well-established and remarkable thermal properties of ice could lead, in the long run, to an alteration of the temperature at the Poles by 45°F. Dr. Simpson's paper contained no mention of this result; but the present situation was that any valid criticism of the geographical theory of climatic variation must begin by pointing out the mistake, if any, in Brooks's recent work. It was not enough to restate the difficulties that he had faced and apparently successfully overcome.

With regard to Wegener's hypothesis, Wegener claimed to have explained many things, but none of the alleged explanations had survived closer inspection. On the geological side he would refer to the work of Lake and Washington. Further, there was no approach to a dynamical theory of the cause of the assumed displacements.

When Dr. Brooks's last paper was discussed[3] Dr. Simpson had argued that the foundering of part of Gondwanaland to form the South Atlantic Ocean was inconsistent with isostasy. The fact that rocks of basaltic composition exist in the earth in several different states, however, opens a way of meeting this difficulty. Ordinary basalt, vitreous basalt or tachylite, and eclogite have practically the same chemical composition, but their densities are about 2.9, 2.7 and 3.3 respectively. There is seismological evidence that the basalt below the continents is in the form of a layer of tachylite about 20 km. thick. If this was to crystallise to eclogite its thickness would be reduced by 4 km., which

[2] See *Geog. Journ.*, Vol. **64**, 1924, pp. 52-53.

[3] *Q.J.R.Meteor.Soc.*, 1926, p. 260.

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would be enough to convert a continent into an ocean bottom without disturbing isostasy. He was not prepared to say that this was necessarily the true explanation, but seeing that the foundering of Gondwanaland had been advocated on purely geological evidence, and had led in Dr. Brooks's hands to the best explanation of Permo-Carboniferous climate yet offered, he thought it was worth mentioning.

Dr. Evans's suggestion with regard to the possible effect of interplanetary matter could be examined easily. The density within the earth's orbit at some time in the past that was required by cosmogony was of the order 4×10^{-15} gm/cm^3. The distance of the earth from the sun being 1.5×10^{13} cm., the sun's radiation had to penetrate 0.06 gm/cm^2 of matter, probably hydrogen, before reaching the earth. This was equal to the mass per unit area of 50 cm. of air at the earth's surface. Whether it could have any important thermal effect seemed doubtful; further, it might well be much less than the increase in the depth of the atmosphere during geological time.

Dr. G. C. SIMPSON writes: At the meeting there was no time to reply to the points raised in the discussion, and as further contributions have been added subsequent to the meeting I propose to reply to the discussion as printed above.

The first thing which strikes me is the way in which my critics have ignored my arguments. My contention is logical and self-contained, and in spite of repetition must again be stressed. The argument runs thus: The present temperature of latitudes higher than $\pm 35°$ is maintained by heat transferred from equatorial regions through the agency of the general circulation of the atmosphere. If the temperature of these latitudes were raised, the temperature gradient between the Equator and the Poles would be decreased and with it the general circulation of the atmosphere. If the new temperature distribution were stable we should have the paradox that compared with the present conditions, also stable, the temperature of the higher latitudes would have been raised while the supply of heat would have been decreased. That is the argument which must be shown to be wrong. It does not help to say that Dr. Brooks has shown that, to quote Dr. Jeffreys, "the thermal properties of ice could lead, in the long run, to an alteration of the temperature at the Poles by 45°F."; it must be shown how the changed temperature can be maintained as well as induced. How would the polar regions maintain their high temperature during the warm periods when the transport of heat by both air and water is cut off by the reduction of the general circulation of the atmosphere?

As I said at the meeting, Dr. Brooks's mathematics has no more value than the assumptions which he employs. He makes the assumption that if C is proportional to the atmospheric circulation and W the width of a channel, such as that of the Gulf Stream Drift, the heat transferred will be proportional to CW. This is just the kind of fallacy which mathematical treatment leads one into unless it is constantly checked by reference to the actual conditions. Now in the southern hemisphere C is at least as great as in the northern hemisphere, but W in the northern hemisphere is the width of the Gulf Stream while in the southern hemisphere it is the whole circumference of the globe between latitudes 40°S. and 60°S. Does Dr. Brooks say that the transport of heat by ocean currents into the Antarctic is greater than it is into the Arctic? If so, it has surprisingly little effect on the tem-

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perature, and that is the only effect which interests us in this discussion. In the second point discussed by Dr. Brooks he does make an effort to answer my question as to the disposal of the extra heat brought into polar regions during his cold periods. He says: "The large surfaces of ice have a remarkable capacity for getting rid of heat by reflection to space"; but this is only true of short wave radiation such as we have in sunlight. The extra heat transported by the atmospheric circulation gives rise to long wave radiation only and to this radiation snow is as black as soot!

Sir Napier Shaw objects to my use of the mean annual temperature averaged along a circle of latitude as the criterion of the climate. I acknowledge no fault in the procedure, for in the first part of my paper I was discussing climatic zones, and a climatic zone must be characterised by its mean temperature. When geologists say that they require a sub-tropical climate, they mean a climate which is found to-day on the borders of the tropical zone and they would not be content with a mere change in the seasonal extremes which may be found within the frigid zone. Nowhere north of latitude 60°N. or south of latitude 60°S. is there any locality where tropical or subtropical vegetation can grow; if, as I try to show, the mean temperatures of the latitudes have always been similar to those of to-day, then some other than meteorological changes are necessary to explain the fossils of Greenland and Spitsbergen.

Mr. Bonacina is unable to accept my arguments regarding the impossibility of ice extending to sea level in the tropics because Dr. Brooks has "clearly shown under what conditions a tropical snowline down to 6,000 feet is possible or conceivable." In the hypothesis which appeals so strongly to Mr. Bonacina, Dr. Brooks has certainly postulated a number of things from amongst which I will only quote a few: (*a*) a continental plateau which has no counterpart anywhere on the earth's surface at present, and which, in spite of what Dr. Jeffreys says, is almost irreconcilable with modern ideas of isostasy; (*b*) a monsoon blowing all the year round right across this plateau which rises to a height of 10,000 or 15,000 feet; (*c*) such a heavy layer of clouds that an ice sheet can form over the whole of the plateau even directly under the equator; (*d*) an atmosphere full of volcanic dust. Mr. Bonacina is certainly right in saying that there is "nothing in the present climatic status of the Himalayas or the tropical Andes analogous to this." But when Dr. Brooks has been granted all this he still feels unhappy about the ice in India and has to admit that even then there must have been "exceptional topography" in the Indian region. Dr. Brooks may be right; I can no more *prove* that he is wrong than he can prove that he is right; but to say that Dr. Brooks has clearly shown anything is surely a misuse of the English language.

Like my other critics, Dr. Jeffreys brings no arguments to disprove my main contention that the temperature gradient along the meridians is governed by the general circulation of the atmosphere. Now Dr. Jeffreys is a mathematician of no little repute; I should therefore be glad if he would turn his mathematical abilities to the problem of how a higher temperature in polar regions is consistent with a reduced general circulation of the atmosphere. When he has done that I shall be prepared to consider the theory of an ice-free polar ocean.

In conclusion, I would like to express my thanks to Sir Edgeworth David and Dr. Evans for attending the meeting on June 15 and for making valuable contributions to our discussion.

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FLIGHT TO INDIA OF THE SECRETARY OF STATE FOR AIR.

A special meeting of the Society was held in the Society's Rooms on the afternoon of Thursday, April 28, at which the Fellows and their friends had the privilege of being addressed by the Right Honourable Sir Samuel Hoare, Bart., C.M.G., M.P., Secretary of State for Air, on the subject of his recent flight to India.

The PRESIDENT, when welcoming Sir Samuel and Lady Hoare, referred to the close alliance that had grown up in recent years in England between aeronautics and meteorology, an alliance which was based on common interest and was therefore likely to be long-lived. As one who had spent a great part of his life in India he was peculiarly qualified to appreciate something of the real value to India and its Meteorological Service of a flight such as that which Sir Samuel and Lady Hoare had accomplished.

Sir SAMUEL HOARE then addressed the meeting as follows:—I am here to-day to talk to you about our flight to India, chiefly from the point of view of the weather, and of the help that I received from weather reports during that long journey. From the very start the question of meteorology came into great prominence. There were two questions that we had to decide at the very beginning of our plans. There was first of all the question when we should make the flight, at what season in the year? Then there was the second question, what route should we select as the best from the point of view of weather between England and India?

With reference to the first question, we had no choice. If I had had a choice, I certainly should not have chosen Boxing Day, the end of December when the days are shortest, and when the weather in western Europe is almost at its worst. But it was a choice between going in December or not going at all, for I could not make a journey of that kind whilst the House of Commons was sitting, and I therefore had to make it during a Parliamentary recess; and it would have been impossible for various reasons to put off the journey until the summer recess in August and September. So that, in spite of the dismal weather reports that my friend, Dr. Simpson, provided me with, we had none the less to settle to make the journey during the Christmas recess, that is to say towards the end of December.

Then we had the further question, the answer to which mainly depended upon weather reports: what route should we select, particularly across Europe? There are three possible flying routes across Europe to the East. There is the route by Constantinople, either by the Balkans or by Poland, and there is the more central route by Italy and Athens, across the Mediterranean to Crete, arriving in Egypt at Sollum on the frontier between Cyrenaica and Cairo or Bahar in Alexandria.

A third alternative, and the one which we eventually selected, is to cross France by Dijon and Marseilles, to go down the coast of Italy from Pisa, then to pass the Straits of Messina to Sicily, to land at Malta, arriving at the African coast, close to Tripoli.

We studied very carefully the past weather reports connected

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with each of these three routes, and we came to the conclusion that at the end of December we were more likely to avoid the two chief obstacles from the point of view of the weather, fog and snow, on the westernmost route. From these two points of view it was safer to select this western route by Malta and Tripoli. It was interesting to an amateur like myself to study the different weather conditions between these three European routes. It was, for instance, a matter of surprise to me to find that at Athens there was a very high percentage of fog to be expected in the month of December. I had seen Athens when the atmosphere was very clear, and I had always connected it with bright sunshine and blue skies; it was a curious fact to find that based upon the averages of past years in the month of December, there is a considerable percentage of fog at Athens.

We started off on Boxing Day, Lady Maud and I, very nervous about one thing and about one thing alone. We were not in the least nervous about the reliability of our machine or its engines, we were not the least nervous about getting to our destination once we had started, but we were genuinely nervous that when we went down to Croydon Aerodrome very early, before sunrise on the morning of Boxing Day, we should find a thick, London fog, and we should sit there for hour after hour, and then have to go ingloriously back to the house that we had just left to the amusement of our friends who had all gone to see us off on what they imagined was going to be a great journey. Fortunately, that particular morning, although it was very cold and very windy, as we subsequently discovered in the flight, particularly between Croydon and Dijon, it was very clear and we got off the aerodrome absolutely on the tick of time. That was the beginning of the journey, and I do not propose this afternoon to take you in detail over the whole course of it. I would rather generalise upon the more prominent weather conditions that struck me both upon the outward and upon the return journey.

Upon the whole I think we may say that we had bad weather, worse weather than might have been expected, during the whole of the flight. We certainly had every kind of variety of weather. I think that is one of the aspects of a flight of this kind that immediately strikes a passenger, the great changes in weather that you meet with in a comparatively short time. For instance, to give you a particular example, we started upon the second day of our journey from Marseilles in a thick, white fog, a very unexpected weather feature to find so near the Riviera. We were doubtful, in fact, whether it was wise to start, but we did start and very soon got out of the fog and into the most glorious sunshine—the kind of morning that you see described in the advertisements of the Riviera, but which you seldom find when you go there from your own experience, anyhow, from my own experience. We flew along just out to sea, quite close to the Corniche Road, seeing the motors on the road going almost on a level with the machine in which we were flying, without a breath of wind, and in beautiful hot sunshine until we got to Pisa. At Pisa we found heavy rain, and from Pisa on to Naples we could not have had worse weather. We flew down the line of the Apennines with heavy rain and very

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bad visibility; indeed, we were doubtful whether we should arrive in Naples in conditions in which we could see to land upon the rather small aerodrome there.

The following day, when we flew from Naples to Malta, we had beautiful weather between Naples and the Straits of Messina; when we got into the Straits of Messina we were thrown about in a way that can only be likened to a tennis ball being hit over a net; between Scylla and Charybdis, we could not have had a more bumpy passage. Again, we had it very bumpy from Sicily to Malta, with a gale of wind, very heavy rain and clouds so thick that our pilot and navigator decided it was better to fly very low and below the clouds rather than get up above them. It is interesting from the point of view of weather that we should have flown below the clouds that day; it is also interesting from the point of view of the big developments in civil aviation that the pilot and the navigator should have had such confidence in an entirely new machine with three new engines that they should have risked flying across the Mediterranean in a land machine without floats with a land undercarriage at a height that never reached 500 feet.

Then, taking the journey a stage further along the coast of North Africa we had good weather; we had a long sea passage to make here across the Gulf of Sidra, the Syrtis Major of classical history, and it was fortunate we had good weather here, for 350 miles across the open sea is a long stage to make in a land machine. We were flying out of sight of land the whole of the morning, but we fortunately had a following wind and made the journey very quickly and easily. Then again across the coast of Tripoli and afterwards to Cyrenaica, and along the Egyptian coast we had beautiful weather. We had beautiful weather also the whole way from Palestine and Trans-Jordania to Baghdad; extraordinarily beautiful weather, for instance, when flying across the Dead Sea it looked bluer than the Mediterranean with a beautiful view of Jerusalem and Bethlehem. So on to Baghdad, making very good time the whole way, doing our day's journey of about 700 miles a day quite regularly and punctually, dividing it into two stages, the first stage taking us on until about luncheon time when we landed to have luncheon and re-fuel, and then on again in the afternoon until sunset when we landed at our destination to spend the night.

Beyond Baghdad to Basra, and from Basra to Bushire we again had beautiful weather and a following wind that often took the speed of our machine up from its normal speed of 100 miles an hour to 110, 120, or even 125 miles an hour.

Our next stage was Bushire to Jask, making between Lingeh and Jask a detour across the Persian Gulf to give us an opportunity of seeing this stretch of the Arabian coast; a curious and uninhabited coast with very high mountains, and I should think as wild a bit of coast as any in the world. Jask is one of the points of the Indo-European Telegraph Co., and is, I believe, chiefly famous for the fact that it has the smallest rainfall of any place in the world. At Jask we arrived in good weather in the evening, and the weather reports that we were getting all seemed to point to the fact that the weather was going to remain good,

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and that we should be able to get up to Karachi the next day in accordance with our programme. In the evening we walked about on the desert, and one could not have had a clearer evening, or what seemed to promise better weather on the following day. We had a very early start to make, for the landing ground was several miles from where we were staying the night, and that meant a long trek upon camels to the spot where we had left the machine on the desert. We had to leave our house almost before it was daylight, and it was only as it became lighter that we realised that, instead of the clear morning that we had expected, the visibility was very bad and there was a general appearance of a very thick sea mist. When we got out to the machine we had a long discussion as to whether or not we had better start. Unluckily for some reason or other the weather reports had not come in as early as we had expected them, and we therefore had to make our decision with only the reports from the previous evening. Finally, after waiting about on the desert for some time, we settled it was worth making a start, hoping that with our big range of from four to five hundred miles we should be able to fly through or over the sandstorm—for the mist was quite obviously a local sandstorm—and get out of it and find our destination, which was Pasni, for luncheon, and then afterwards Karachi in the evening clear enough for landing.

Well, we started, but before we had gone more than a few seconds, we realised that the storm, instead of getting better, was getting worse and worse, and it soon became so thick that the pilot and the navigator decided that it was not safe to fly along the coast, for the coast along this stretch of the Persian Gulf is a coast of sheer mountains rising abruptly from the sea with no shore or flat landing ground if a forced descent became necessary. Obviously, it would have been extremely dangerous to fly over a country of that kind in a sandstorm in which we could not see more than a few yards away from the aeroplane. Accordingly, the pilot and the navigator instead of following the coast turned out to sea, and came down as low as possible over the sea in order to make a turn and try to get to Jask. We came lower and lower; at first I could not make out what was happening as I saw the altimeter dropping from 4,000 to 3,000, 2,000, 1,000, 100 feet, and when I saw it get to 50 feet I thought the end of the world was beginning to come. Eventually, it got down below 20 and there was a point at which we were only 12 feet over the sea. The pilot had to go down as low as this because the visibility was so bad that otherwise he could not have made his turn; when he had almost reached the sea he made his turn, came back very low over the sea and got back to a point somewhere near where we left the coast. He then coasted very cautiously along the edge of the shore until we got back to the landing ground at Jask, with a strong wind behind us in an atmosphere that was as thick as a really bad London fog. Our pilot made the most amazingly fine landing within quite a few yards of the point where we left Jask in the morning. I asked him when we all got out of the machine how it was he had ever been able to find in the darkness this point which looked to me just like any other point in a desert that goes for thousands of

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miles. He and the navigator told me they had noticed a small heap of stones as they were going along the landing ground in the morning, and they had noticed it as they came back and identified the point by that means. That shows the alertness and quickness of eye of the pilots and navigators of whom we are so proud. If they had not noticed this landmark, obviously our position would have been a great deal less secure than it proved to be.

I have given you that rather detailed description of what happened that morning to draw your attention particularly to the weather side of it. Here was a storm that sprang up very suddenly with little or nothing from which to forecast it the night before, and a storm that we found afterwards was one of the worst that has ever been known in the Persian Gulf or the Arabian Sea, and which had a front, not of the few square miles we might have expected, but a front of 2,000 miles. When we reached Karachi we found that the storm had travelled down the eastern coast as far as Karachi, and down the western coast of the Gulf as far as Aden, so you see how very wise the pilot and the navigator were to turn back. If they had taken the view that we could push through the storm and that after three or four hundred miles we should get out of it, I do not know what would have happened. We should never have been able to identify any landing ground, and after 400 or 450 miles the machine would have had to come down for want of fuel, but the fact that both Captain Woolley Dod and Captain Johnston, the pilot and the navigator, knew something about the weather in those parts, and the fact that they had both experienced sandstorms in Irak, stood us in very good stead, and made them in a few minutes take the essential decision to turn back instead of trying to push on through the storm.

We purposely kept a day in hand for our outward journey; we felt that weather and other conditions were uncertain, and that, therefore, it was quite possible we might lose a day somewhere. We lost our day in the sandstorm at Jask, but it did not delay by an instant our final arrival in Delhi. We arrived in Delhi at the exact moment at which we said we would arrive. We had told the Viceroy we would arrive at 12.30 on a particular morning. At 12 o'clock we were so near Delhi that we had to make various detours in the country to avoid arriving too soon, and absolutely on the tick of time—I think accurately it was 12.29—we landed upon the aerodrome at Delhi.

In India itself I had some experience of weather conditions upon the North-West frontier, where I spent a good deal of my time visiting the Air Force stations on the frontier, and in flying from one end of the frontier to the other. There, again, I was very much impressed by the quickness of weather changes. I remember, for instance, one day I was staying at Peshawar, we had the most perfect weather, one could not possibly have had better weather conditions. The next morning there was an earthquake; we were all woken up early in the morning and we were told it was an earthquake of rather exceptional strength for that part of the world. At the same time the weather upon the frontier changed completely, becoming so cold that one almost died of cold after two or three hours' flying in an open machine. The sudden

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change from quite hot weather and bright sunshine to almost an Arctic cold, with snow on the top of the hills and heavy cloud, made it impossible for us to fly on one day, as we had hoped, from Peshawar to Quetta.

Again, on our return journey, we were to start from Delhi, and as we went out to the aerodrome early in the morning we found, what I should think was unique in the weather history of Delhi at that time of the year, a thick, white London fog. It was very unlucky, having escaped fog in London, to find it at Delhi, and to find it at the moment when we wanted to start upon our return journey. There had been a very heavy rainfall after a long drought on the two previous days, and the result was this thick, white fog that delayed our departure for more than two hours. There, we had an experience exactly the opposite of our experience at Jask. We had a long programme to carry out, for I had various engagements at Karachi that evening and I did not wish to cancel them. We therefore made a start and we found in this case that the fog was only a local fog, unlike the sandstorm at Jask. After about half an hour we got through it and into sunny, though very bumpy, weather between Delhi and Jodpur, and afterwards between Jodpur and Karachi.

For the rest of our return journey I think the only episode from the point of view of the weather that I need mention was the weather that we met with between Baghdad and Cairo. On the way out we had flown the stage from Cairo to Baghdad in two journeys, stopping for the night at Ziza, the aerodrome of Maan, the capital of Trans-Jordania. On the way back I was very anxious to hurry on to Egypt where I had to discuss various questions with Lord Lloyd, and I did not want to stop a night at Maan and delay my return. Moreover, also I wished to be in the first civil machine that made the journey in a single day. It is a journey of nearly one thousand miles, and that is a long journey for a big machine with a number of passengers and quite a considerable weight of luggage.

We started off early in the morning from Baghdad congratulating ourselves on the fact that we had a strong following wind of more than 20 miles an hour. I should think at one time our ground speed was about 125 miles an hour, that is to say 25 miles an hour added by the wind to our regular speed of 100 miles an hour. But there, again, we had a very quick change of weather, and when we were about an hour outside Baghdad the wind changed entirely round, and instead of having a wind of 25 miles an hour with us, we very soon had a wind of 40 miles against us, that is to say our speed was reduced from over 120 miles an hour to below 70 miles an hour; at one time it fell as low as 65 miles an hour, and during the greater part of that day we had this strong wind in our teeth, and were averaging little more than 70 miles an hour. That is a very good example, so it seems to me, of the effect of the wind upon a flight of this kind. There, in the space of about an hour, instead of finding the wind a help to the extent of 20 or 25 miles an hour, we found it a hindrance to the extent of more than 40 miles an hour. It had a very definite effect upon our journey that day; instead of having a comparatively comfortable

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journey and completing our thousand miles and arriving in reasonable time at Cairo, we found ourselves at Ziza in the late afternoon when it was already getting dark, with the difficult question to decide whether we should press on that evening, running the risk of flying over the desert for a considerable time in complete darkness. Well, by that time we had such complete faith in our pilot and our navigator and the machine and the engines that we decided to press on, and the result was that from a point not very far south of Ziza, Beersheba, up to Cairo, we flew almost entirely in the pitch dark entirely by the compass. Now that, I think you will agree, would have been incredible a few years ago, a great passenger aeroplane carrying a number of people flying in the pitch dark over that most deserted stretch of desert between Beersheba and the Suez Canal, and finally arriving absolutely accurately over the aerodrome at Heliopolis and landing as easily and comfortably and safely as we should have done in bright daylight at an aerodrome like Croydon. It seems to me to show that, whatever critics may say, civil aviation and civil aeroplanes have made very definite progress during the last three or four years. No one would have dared, I feel sure, three or four years ago, to have made the attempt to fly from Palestine to Egypt in complete darkness at the end of a very stormy day and at the end of a thousand miles' stage.

After that we left our machine at Cairo with great regret; we would much have preferred to have flown back from Egypt to London, but the machine was required to begin the regular passenger service between Egypt and Basra, and I was anxious on no account to delay the starting of that service. The result was that we had to commit ourselves to a very rough Mediterranean and a very shaky train journey across Europe, comparing, at any rate in my view, very unfavourably with the conditions in the aeroplane that we had just left, and to put the coping-stone upon this return to—how shall I describe them?—the more conventional forms of travel, we arrived in Paris to find we were in the midst of that dreadful fog from which London and Paris suffered for so many days at the beginning of February. That you will remember stopped our actually flying back from Paris to London. From the point of view of the flight, it was a matter of no importance at all. Our flight had been carried out as we had planned it in every respect, the actual return from Paris to London in one of the ordinary passenger machines would have been simply a joy-ride or a little by-play at the end of it, and I hope you will agree that the fact that we were held up by fog in Paris and were not able to make this joy-ride at the end in no way detracts from the success of the 10,000 miles that we had completed between here and India up to programme in every detail from start to finish.

All this description that I have given you of certain aspects of the flight emphasises the great importance of meteorology to the creation of any long-distance air service, whether it be an aeroplane service or, perhaps still more, an airship service. From start to finish, every day one had it impressed upon one's mind that one of the most essential conditions of any long-distance air route is a properly organised meteorological system. When we were within reach of our own organisation we had few or no difficulties, where

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we were without it or where it was inadequate, as in the nature of things it was along the Persian Gulf, there we found ourselves in difficulties. In India again the Indian authorities were most ready to give us all the help at their disposal, but I feel sure they would be the first to say that there still needs much development to take place if regular civil lines are to be organised to and from and across India. I remember when we were standing upon the aerodrome at Delhi in the fog, wondering whether we should start or not, and raining telephone messages and telegrams upon anybody who was likely to give us weather reports or forecasts of what was going to happen during the day, we got this answer from the stationmaster of a station down the line: "Weather conditions excellent, everything up to time, the express has just run through two hours late." I do not suggest that that incident is in any way typical of the meteorological service in India, nothing could be further from the case; the meteorological service took the greatest interest in our flight, and I know did everything they could to facilitate it and to make it as safe as they could from the point of view of the weather reports, but it all comes back to this central fact, that as we develop our air lines, particularly as we develop our airship lines—the airship depending not only for its safety but also for the economy of its working upon making the best use of the prevalent winds—we shall have to have a wider meteorological organisation than exists to-day, and we shall have to persuade other countries where the organisation is not as good as our own to start or develop organisations, and to make it possible to develop these long-distance routes.

I see by the clock that I have already gone on a great deal longer than I intended; I only hope I have not wearied you with details, and I shall feel that I have not spoken in vain if I have interested you as students of meteorology in the formation of these long-distance air routes, and if I have made it quite clear, speaking as the Secretary of State for Air, how great is the importance that I attach to the development of meteorological science.

There is only one more observation that I should like to make. I fear that you may go away with the impression that our journey was a journey of great dangers and many risks. Naturally to-day I have emphasised the more conspicuous weather conditions. That was what you wanted me to speak to you about, but I think the lesson to be drawn from the flight is not that the journey was a very dangerous journey, but that in spite of the worst possible weather we were able to carry it out safely and punctually, and I venture to think that is really the important fact that emerges from the flight. It was a long-distance flight made regularly and punctually up to time every day and in the face of the worst possible weather. If the British public will get that aspect into their minds, then we may look forward to the hope being realised that the route along which we flew for the first time in a civil machine will become one of the regular highways for traffic and intercourse and trade. If that result is brought about some time in the future, Lady Maud and I will feel our journey has not been in vain.

At the conclusion of the meeting a vote of thanks to Sir Samuel Hoare for his address was proposed by Sir NAPIER SHAW and seconded by Mr. FRANCIS DRUCE and carried with acclamation.

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REPORT ON THE PHENOLOGICAL OBSERVATIONS IN THE BRITISH ISLES FROM DECEMBER, 1925, TO NOVEMBER, 1926.

No. 36, NEW SERIES.

By J. EDMUND CLARK, B.A., B.Sc., IVAN D. MARGARY, M.A., and RICHARD MARSHALL, F.R.A.S.

[Read June 15, 1927.]

EXPLANATORY NOTES.

Year Dates.—The figures in the tables and text give the number of days before or after midnight, December 31. Thus

−31— 1=Dec.	60 —90=Mar.	152—181=June.	244—273=Sept.
1—31=Jan.	91—120=April.	182—212=July.	274—304=Oct.
32—59=Feb.	121—151=May.	213—243=Aug.	305—334=Nov.

In Leap Years add one day to the number after February.

Symbols.—In all tables, except Table IX., figures in *italics* represent interpolated values. In Tables III. and XI. these are used for calculating the *Station* means, but such figures are not used in computing *District* means. In preparing the tables all dates supplied by the observers are tabulated and critically examined. The most erratic, with reference to the other observations and the average date in each District, are then rejected and excluded from the Station and District means. They are not shown in Tables III. and XI., but in Table IX. they appear in italics.

From exigencies of space we have to restrict the tables compared with the records contained in the preliminary tabulation. Only those stations are printed which, in Table III. include seven or more records; in Table IX. include three birds or three insects; and in Table XI. eight birds, except in sparse districts. The original tables and the actual observers' reports are stored for reference, together with an abstract of their notes analyzed under ten or more different subjects.

District means based on two observations are shown thus ( ), and if on a single record thus [ ].

Except in Table I., where they have the usual significance, the signs + and − indicate that the event was later than, or earlier than, the 35-year average date.

INTRODUCTION.

Entering upon a second period of 35 years, a few preliminary words seem desirable. Thanks to the growing interest in our subject we can report a further increase in our Stations, which now number 373. Again we tender our most hearty thanks to all who have helped in the work.

This advance has been shown by increasing interest in International Phenology, by a request for short articles for nature publications, and by nearly 90 inquiries, thanks to a note inserted by Mr. Morris Bower in his report on winter thunderstorms, while

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for the first time two phenological papers were placed on the agenda for the annual meteorological conference, arranged by the Ministry of Agriculture and Fisheries for the staffs of the Agricultural Colleges. Most important of all, however, as it elicited over 150 inquiries, was the broadcast talk from London by Mr. I. D. Margary.[1]

While many considerations are often involved in rejecting abnormal dates, three dangers are prominent, namely, mistakes in observation or of record and the omission, especially with flowers, of full adherence to the instructions. As to migrants, it is only too easy to miss the first arrivals and last departures. The female brimstone butterfly and the green-veined white are at times mistaken apparently for the small white and bee-flies for bees. Observers sometimes point out that certain selected plants have sub-varieties of early or late flowering tendency, the inclusion of which lowers the value of the records. This is true and, in the more precise scheme which the Ministry of Agriculture is undertaking, plants derived from a common source are to be used. With the Society's wider scheme this precision is, of course, impossible, but the instructions have always asked for observations on average specimens and it is thought that the definite results shown by our collected records imply that a true indication of climatic conditions is obtained. Moreover the inclusion in our tables of district means for single events and means of groups of plants, birds, etc., for single stations, further reduces the risk from erratic records, while providing more concise and useful figures for comparison.

Abnormal dates due to abnormal weather, a fact generally emphasized by their coming in groups, are as a rule retained. 1926 has given us exceptional difficulty in this regard, the record, like the weather, being, as one observer terms it, "most patchy." Outstanding are the frequent reports of cuckoo and swallow in March and of the latter and house martins in November; the premature appearance of flowers and insects in April, after the Easter heat wave, and even more so of migrants, as if the unusual conditions here had been preceded by similar conditions along their route. This last point illustrates what we may hope for from international co-operation.

Turning to the history of the past 35 years, the gradual development of this Report may, we trust, be regarded as evidence of its importance. Our Society indeed took the first step in 1875 under the Rev. T. A. Preston, of Marlborough College, by whom the work was carried on for 15 years. His scheme was based on the excellent work which he had begun there in 1866. The large number of events included, however, even though the number of stations was limited, precluded that systematic evaluation of means and averages which so greatly increases the value of tabulated results. The value of many continental reports would be enhanced and co-ordination rendered easier if means were always available. In some cases only bare records are published. Mr. Preston's work began for Phenology in our islands what Mr. G. J. Symons did in the late fifties for British Rainfall.

1 "The Effects of Weather on Plant Life," *Q.J.R. Meteor. Soc.*, **53**, p. 85.

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When, on the Rev. T. A. Preston's retirement, the work was taken over by Edward Mawley, the necessity of reducing events and working out results had been realised. The year 1890 saw a transition and in 1891 was inaugurated the present series upon lines which have remained practically unchanged. There were then just over 100 stations. The 20-year averages at Marlborough, modified by those for 14 years from some 30 stations over the British Isles from the "Floral Calendar" of the *Natural History Journal* together with averages for six years evaluated by W. F. Miller, of Croydon, were used as a comparison for the means of 13 plants in the various districts, for which means for the eight previous years were worked out from the Society's records. The district average dates were obtained by allowing four days in winter and spring and three days in summer and autumn for each 1°F. difference in mean temperature from that of Marlborough. The plate for flowers, now Fig. 5, showing the mean district dates and variation from the average, was included, with tables giving the estimated value of field and fruit crops. The last were dropped after 1914, partly from war exigencies but chiefly on account of the more complete publications of the Ministry of Agriculture.

The present Report indicates the directions in which expansion of the scheme laid down in 1891 has proceeded.*

In commencing this new 35-year period some reorganisation has been made. Recent developments made it desirable to re-arrange and re-number the tables in the following order:—

Old.	New.	Contents.
I., I.A	I.	Meteorological Factors.
II.	II.	List of Observers.
III.	III.	Main Plant Table.
III.A	IV.	Additional Spring Flowers.
IV.	V.	Main Plant Summary.
V.	VI.	Annual Comparison of Plants.
VIII.	VII.	Mr. Lowe's Trees, etc.
—	VIII.	Plants on the International List.
VI.	IX.	Birds and Insects.
VI.A	X.	Birds and Insects, Summary.
VII.	XI.	Main Spring Migrants.
—	XII.	Rarer Spring Migrants.
VII.A	XIII.	Additional Bird Records.
IX.	XIV.	Major Marsham's Records.

The list of observers is printed afresh this year and the opportunity taken of describing more accurately certain country stations, whose exact positions were previously doubtful. In a few cases, where the post town had previously been used as a guide, it was found necessary to re-number the station, which actually fell in a different map-square. Such cases are noted and in all other stations, where the description has been changed but the station number retained, it implies that the old station has been more accurately described.

The plant tables are practically unchanged, though Table VI. now includes more districts. The new Table VIII. takes additional plants from the international list, as mentioned last year.

The migrant tables have been simplified as explained where they are dealt with on p. 269. In Table XIII. the song thrush

* There were then only five of the present fourteen tables.

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and the last swallow have been included for easier comparison and group means for first song and for autumn migration are now given.

1926 Report.

Weather Summary, Table I.—The official Monthly Weather Report is headed: "A mild year; rainfall about the average and

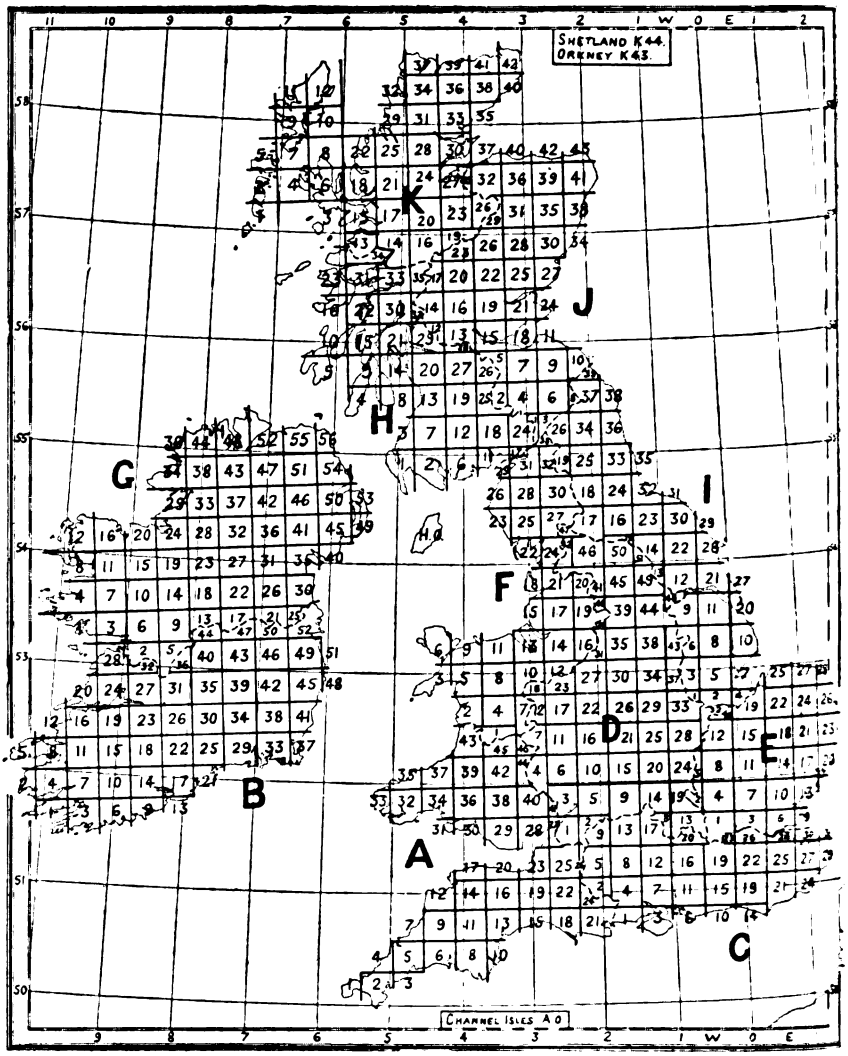

Fig. 1.—Phenological Districts and Areas.
The station numbers are derived from the numbers shown here.

sunshine deficient. March and December very dry; November exceptionally wet; September warm."

Instead of December, 1926, our phenological year begins with that of 1925, which however gave little opening for the first

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stirrings of the new season. Up to Christmas the weekly returns ranged from 7°.5F. to 4°.7F. below normal, the closing week of November having been equally cold. But Boxing Day brought an entire reversal, the last week showing an excess of 5°.5F. From then onward until mid-April warmth prevailed in all districts. Cold then supervened destructively, lasting more or less throughout May and early June. The average excess of 8°.8 for the fourth week of February was the most divergent, but the abnormal warmth in early April around Easter affected conditions to a more striking degree.

By this time a heavy January rainfall had been compensated by a dry March, but after December sunshine was very deficient. There was a daily shortage of nearly an hour in February and about ½, ¾ and ½ an hour in the three following months. Only August and October were in excess, each by about half an hour.

After 1½ inches excess of rainfall in January no month was particularly wet until November gave nearly 2 inches. District totals were, however, most irregular in November. With 4 inches excess little farm work could be done in England SW and the SE was little better. Scotland N was nearly an inch short.

Taking the values for our year the average excess of temperature (0°.8) ranged from 1°.4, 1°.0 and 0°.9 in Eng. E, the Channel Isles and Eng. SW, to 0°.1 and 0°.4 in Scot. E and W; of rainfall (44 mm.) from +130, 100 and 98 mm. in Scot. E and W and England SE to −21 and +17 in Ireland S and N, +2 in Eng. SW; and sunshine (−0.21 hours) from +0.16 and 0.09 hours in Scot. E and N to −0.47 and 0.44 hours in the Midlands and Eng. E.

Accumulated temperatures after Christmas to the end of April were naturally very favourable for growth. May and June form a break, though not a very serious one, after which conditions remained favourable until October. That month was 82° short compared with 116° and 91° in excess in February and March respectively. The October mean temperature (−2°.3) was the worst in the year.

Isotherms and Isohels (Fig. 2, Dec., 1925,-July, 1926). *Isotherm* 51° appears in SW Ireland, not only in SW Cornwall, as in 1925. 50° runs further S from Kent to W Devon, but loops round up the Severn as much as last year, further W lying much as in 1925. 49° replaces 48° over central Wales, but loses its bulge up the east Midlands to S Yorkshire, save for a small outlier round Hodsock within a larger one of 48° stretching up to Scarborough. Isotherm 48° from Norwich, instead of passing north over Durham, turns down the Great Ouse and thence to Cumberland, but keeps S of SW Scotland. From S Antrim it again bulges SW round L. Ree on the Shannon. 47°, after a bulge into the Pennines round the Wash, reappears along the Wear and then crosses to Islay, much as in 1925. Compared with that year 46° lies much further south, passing from Dundee to Skye instead of just round Caithness, where it is replaced by 45°. Thus, influenced chiefly by the inclusion of December, the 1926 isotherms lie decidedly further south than in 1925, or the exact reverse of the floral and migrant isophenes.

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Isohels likewise run much further south, though with the same range of hours, from five to three, as last year. Isohel 5 crosses the Channel Isles instead of from the Thames to N Cornwall, a course actually N of 4.5 hours in 1926, which passes W from Dover round Sussex to the I. of Wight, and then south of the coast to Torquay, crossing to Bideford and W Pembroke. Isohel 4 is again coastal from Boston to the Thames, then crosses to the Severn, whence it is coastal again round Wales to Cumberland, crossing north of the I. of Man to the SE Irish coast. The 3.5 hours line has a curved figure like a boomerang, passing NE

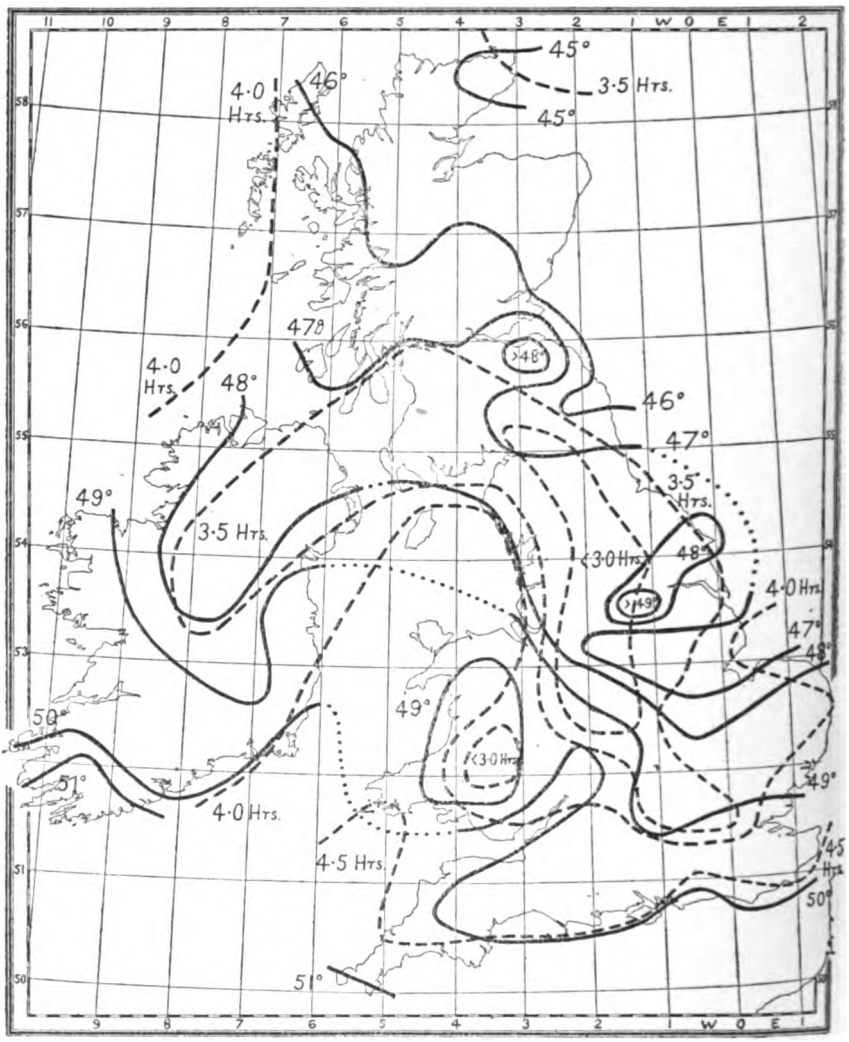

FIG. 2.—Isotherms (reduced to sea-level), or lines of equal temperature, and Isohels, or lines of equal sunshine, during the eight months December 1925 to July 1926.
Isotherms ——— Isohels — — — —

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from L. Ree over Antrim, bending SE in SW Scotland, covering all non-coastal parts to the Humber-Mersey line and reaching down to London with a separate area over Central Wales. It reappears over the Orkneys and Shetlands in contrast with the 4-hour isohel coming over the Hebrides. The bulk of Scotland and Ireland lie between 3.5 and 4 hours. Least favoured was the Pennine area and Midland manufacturing districts, where isohel 3 hours extends from E of the Solway nearly down to the Severn and Upper Avon.

Floral Isophenes (Fig. 3; based on the 12 plants, hazel

Fig. 3.—Weekly Floral Isophenes, or lines of equal flowering dates, from 117 to 152, for the 12 plants Hazel to Greater Bindweed.

117=April 27. 131=May 11. 145=May 25.
124=May 4. 138=May 18. 152=June 1.

Conjectural..... 1926 _____ 124 Average (35 years 1891—1925) — — — — 124

(The effect of high ground is clearly evidenced, especially in the North.)

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to bindweed). The average values used are this year based on the 35 years average (1891-1925), Fig. 3A. There are no significant changes in these from the 30-year isophenes previously used. Increased knowledge of the Scotch Highlands necessitated inclusion of a larger area by isophene 145 days and minor changes occur in 131 by Dundalk Bay, in 124 by the Wash, and in 117 on the south-east coast. It is satisfactory to find that these average isophenes appear very well fixed and unaffected even by the inclusion of average values at some newer stations. In all 155 are used. Where the records do not cover the whole 35 years, those missing are weighted by the method employed in 1921 by the late Mr. H. B. Adames, who was assisted by Miss B. Farley.

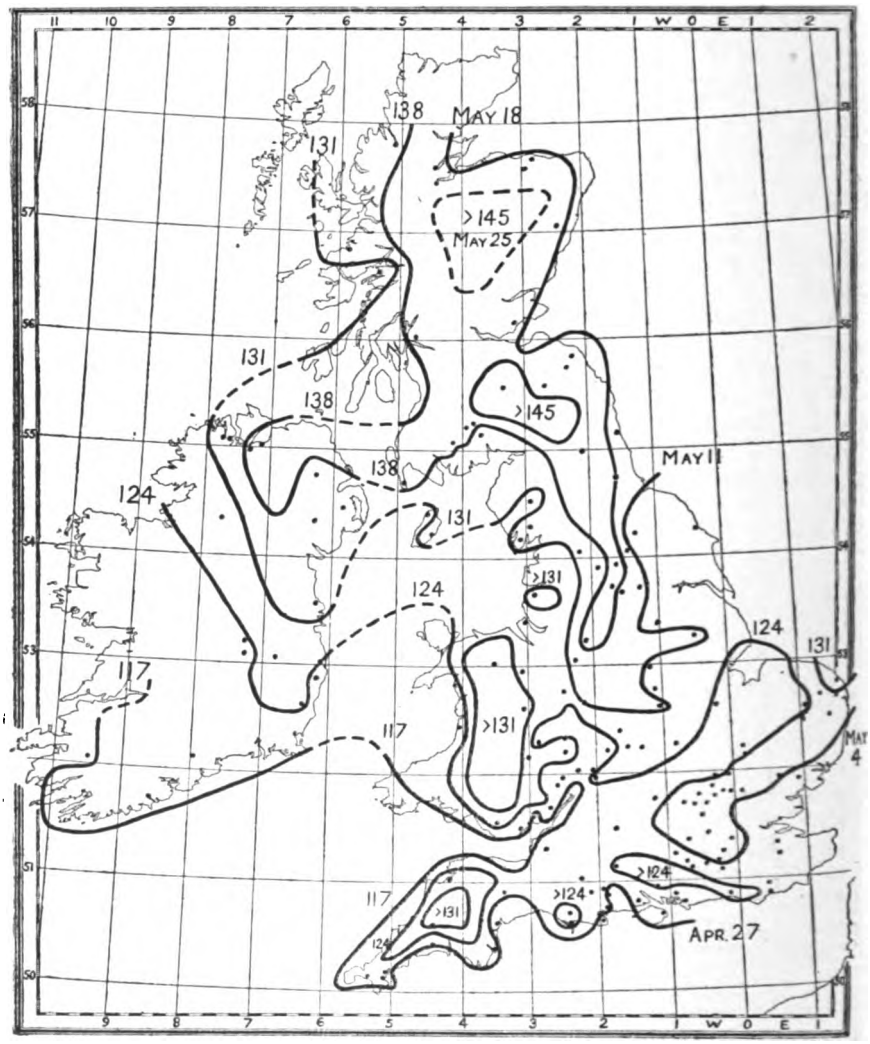

FIG. 3A.—Average Floral Isophenes (35 years, 1891-1925).

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The 1926 isophenes have everywhere an earlier tendency than in 1925 (itself distinctly earlier than 1924) by a week or more in most areas. The chief isophene, 124, crossed the country from Cromer via Grimsby, Derby, Barrow and Belfast to Co. Donegal, practically the same route in England as 131 in 1925. Isophene 117, after enclosing a large area of Essex, Herts, the Thames valley, Kent and Sussex, follows the south coast to Devon, which it encircles together with the Severn valley and Welsh coasts. In 1925 it only appeared in the I. of Wight. The late areas in the north are less pronounced, isophene 145 being the latest shown. The disposition in Ireland is peculiar, though everywhere earlier, especially in the north. The small early area enclosed by isophene 117 near Kilkenny is well defined, though the general tendency in SE Ireland was towards later dates.

Floral Isakairs from 1891 to 1926 have been worked out, based on our fresh average isophenes for 35 years, charted in Fig. 3A.[2] This fulfils the first stage of the hope expressed by Mr. Margary in the discussion last year. He has further worked out, in preparation for this, all the unplotted isophenes from 1891. Space in our Report does not allow such full discussion as the work merits, but it is hoped to do this in a separate paper.

Isakair O in 1926, apart from a series of small but detached areas, after passing round Dornoch Firth, with the highest divergence of 12 days later at Cromarty Firth, passes in a wide sweep, first SW to Donegal, thence via Wexford and N Pembroke through S Wales to the head of the Bristol Channel, along the N coast of which it sweeps back via Cork to Galway Bay. Isakair —5 days runs closely parallel as far as Cardigan Bay, semi-circling round a large area of 10 days early. The only areas appreciably late are in SE Ireland and the west slope of the Pennines. These areas each include a record of nine days late, compared with 12 days early at Cromarty Firth, on the NE Irish coast and in W Bucks. The greatly extended neutral zone, along which flowering coincides with the 35 years average, measures nearly 1,300 miles from end to end. This exceeds any previous years except 1915, with 2,200 miles, and 1897 with 1,400. In all three years the late values cover very limited areas. At present the average isotherms and isohels for the 35 years are not worked out to provide a basis for similar divergencies, or a comparison with these floral isakairs might bring out important points.

Floral Comparisons (Fig. 5 and Tables III. to VIII.). Last year we commented on the unusual contraction from district to district in the flowering periods. It averaged only 75 per cent. of the normal. 1926 almost repeats this, being under 80 per cent., as indicated in Fig. 5. This figure also shows graphically the steady increase in earliness to the blackthorn event, given in Table V. as 17 days and 16 days respectively for S Britain (*e.g.*, S of the Humber-Mersey line) and the British Isles. It brings us into March. Marked earliness continues to the may event, which

[2] The close approach of the 35-year isophenes to those for 30 years implies so well-established average values that we shall be encouraged to use them for future years just as the Meteorological Office still relies on its averages 1881-1915.

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for S Britain actually falls on April 30, despite the late April check. That, much intensified in May, cancelled earliness to the dog rose and substituted decided lateness for knapweed to bindweed in S Britain, though not in the whole area. The average time lapse, hawthorn—white ox-eye, is 15 days. Conditions in 1926 made this 29 and 26 days respectively.* This is well brought out

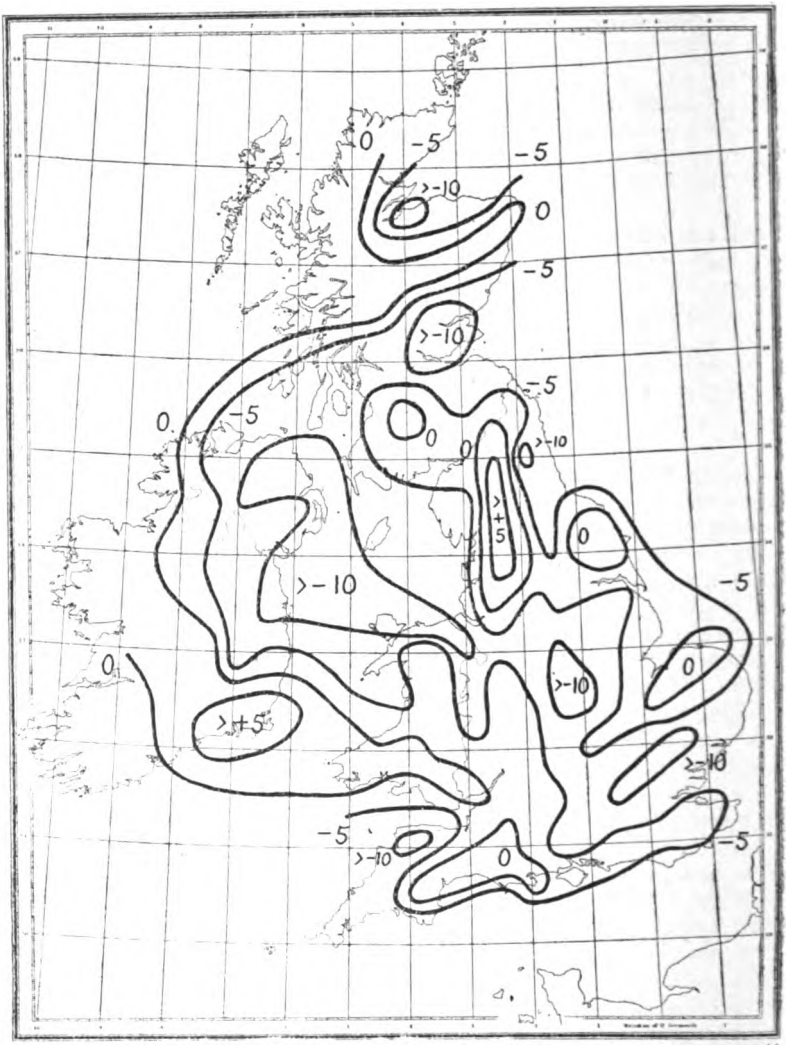

FIG. 4.—Floral Isakairs, or lines of equal divergence (*Gr. ise akairia* equal unseasonableness) from the average flowering date, for the year 1926.
The lines indicate the distribution of differences of 5 and 10 days before (−) or after (+) the average date of the region for the period 1891-1925.

* Mr. R. Marshall's graphs for the separate flowers from 1891 show that this gap of 29 days for England and Wales is a new record. The previous was 26 days 32 years ago in 1894. Then, however, the record for all Districts was 27 days or one more than in 1926. This indicates that cold effects were then most accentuated in southern Britain.

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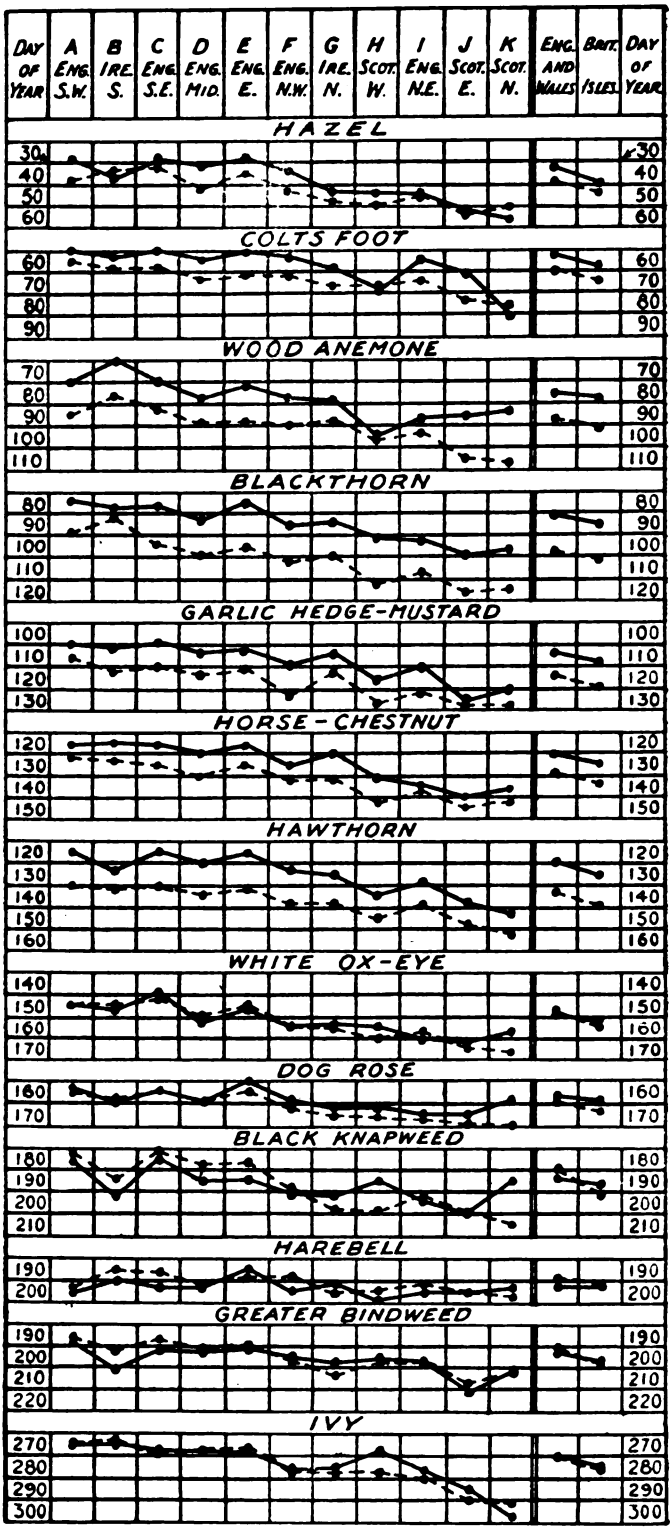

Fig. 5.—Dates of Flowering of Plants by Districts.
1926_____ 35 years' average - - - - - Conjectural . . . . . .

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in Table VI. Here, to the average of mean flowering dates for the whole series, is now given that of the seven up to hawthorn, which represent Spring, and of the next four, which stand for Summer. The former average 10 days early for England and Wales, 11 for the British Isles; the latter two days late and one day early respectively.

MR. LOWE'S RECORDS (Table VII.).—As from its first inclusion in 1915, this tabulates seven important seasonal stages for some 90 trees and bushes. The three spring stages in 1925 averaged a day late; in 1926 over 12 days early, or April 21st. The "Full Leaf" column (mean 15) is specially striking, maple being 27 days early, or April 15th. It just missed delay by the April cold and profited to the full by the Easter heat.

(*Continued on page 254.*)

FIG. 6.—Migrant Isophenes (lines of equal arrival dates) 1926. Based on the 29 birds and —— stations of the Migrant Table. See Table XI.
also Isophene Stations 1926: Floral •, Migrant ×, Floral and Migrant ⧗.

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TABLE I.—METEOROLOGICAL FACTORS, 1925/26.

+ indicates above the average, −below it.

A. *Daily Mean Temperature in Degrees Fahrenheit, Variations from the Average.*

MONTHS.	Mean Dis. A—J.	Chan. Islands 11.	A. Eng. S.W. 8.	B. Ire. S. 10.	C. Eng. S E. 5.	D. Eng. Mid. 4.	E. Eng. E. 3.	F. Eng. N.W. 7.	G. Ire. N. 9.	H. Scot. W. 6.	I. Eng. N E. 2.	J. Scot. E. 1.	K. Scot. N. 0.
December	−2.5	−1.1	−2.2	−2.1	−2.0	−2.5	−1.9	−2.3	−1.1	−3.7	−3.0	−3.7	−3.2
January	+1.7	+1.9	+1.8	+1.8	+1.5	+1.6	+1.5	+2.4	+2.2	+1.9	+1.0	+1.7	+2.4
February	+4.2	+4.2	+4.7	+4.0	+5.6	+5.0	+5.5	+4.:	+3.6	+3.0	+4.0	+2.6	+3.0
Winter	+1.1	+1.7	+1.4	+1.2	+1.7	+1.4	+1.7	+1.4	+1.6	+0.4	+0.7	+0.2	+0.7
March	+2.2	+1.3	+1.6	+2.0	+2.1	+2.3	+2.9	+1.9	+2.1	+2.1	+2.4	+2.2	+2.6
April	+2.5	+1.4	+1.8	+2.1	+1.7	+2.5	+3.5	+3.0	+2.6	+2.5	+3.2	+2.3	+3.5
May	−1.2	−0.4	−1.0	−1.2	−0.9	−1.3	−0.6	−1.3	−1.5	−1.3	−1.1	−1.9	−0.6
Spring	+1.2	+0.8	+0.8	+1.0	+1.0	+1.2	+1.9	+1.2	+1.1	+1.1	+1.5	+0.9	+1.8
June	−0.8	−1.5	−1.3	−1.1	−1.3	−0.9	−0.5	−0.9	−1.0	−0.5	−0.1	−0.5	+0.6
July	+2.2	+1.8	+2.3	+3.2	+1.2	+2.2	+1.3	+3.0	+2.6	+2.6	+2.3	+1.6	+2.2
August	+1.8	+1.7	+2.2	+2.0	+1.3	+2.1	+1.8	+2.0	+1.8	+1.5	+2.1	+1.2	+1.8
Summer	+1.1	+0.7	+1.1	+1.4	+0.4	+1.1	+0.9	+1.4	+1.1	+1.2	+1.4	+0.8	+1.5
September	+2.2	+3.1	+3.2	+2.0	+3.0	+2.6	+3.4	+1.7	+1.7	+1.4	+2.4	+0.7	+0.4
October	−2.3	−0.6	−2.0	−1.3	−2.2	−2.3	−1.6	−2.7	−1.5	−3.3	−2.4	−4.1	−3.8
November	−0.7	−0.4	−0.6	−1.5	+0.7	−0.7	+1.2	−1.2	−1.1	−1.5	−0.8	−1.4	−0.6
Autumn	−0.3	+0.7	+0.2	−0.3	+0.5	−0.1	+1.0	−0.7	−0.3	−1.1	−0.3	−1.6	−1.3
YEAR.	+0.8	+1.0	+0.9	+0.8	+0.9	+0.9	+1.4	+0.8	+0.9	+0.4	+0.8	+0.1	+0.7

B. *Total Rainfall in Millimetres, Variations from the Average.*

[25 millimetres practically equal 1 inch; hence 0.04 inch equals 1 mm.]

December	−10	+30	−15	−32	+15	+ 1	− 2	−21	−22	−42	+19	− 2	− 9
anuary	+36	+49	+52	+87	+34	+29	+14	+ 7	+47	+52	+13	+26	+21
February	+11	− 2	− 2	0	+ 8	+ 7	+14	+19	− 2	+33	+ 3	+28	−12
Winter	+37	+77	+35	+55	+57	+37	+26	+ 5	+23	+43	+35	+52	0
March	−33	−39	−54	−43	−40	−30	−36	−33	−34	− 9	−30	−18	+58
April	+ 5	+37	+ 7	− 2	+42	+ 8	+33	−16	−11	−13	− 6	+11	−13
May	+ 4	+10	− 5	+ 8	+ 1	+13	− 4	+13	+12	− 3	+ 2	+ 4	− 5
Spring	−24	+ 8	−52	−37	+ 3	− 9	− 7	−36	−33	−25	−34	− 3	+40
June	+ 9	+41	+ 6	+ 7	+27	− 7	+20	−10	+ 3	− 2	+30	+ 17	− 7
July	− 3	−30	− 16	− 1	−10	−11	− 6	+ 8	+ 3	+ 8	+11	− 11	− 29
August	−13	−17	− 18	−17	−26	−12	−16	− 1	− 9	+ 4	−11	− 27	− 15
Summer	− 7	− 6	− 28	−11	− 9	−30	− 2	− 3	− 3	+10	+30	− 21	− 51
September	− 6	−49	− 29	−30	−34	−20	−15	+22	+ 3	+10	− 4	+ 34	+39
October	− 2	−18	− 27	−32	−11	− 9	− 2	− 9	+ 4	+34	− 6	+ 38	+13
November	+46	+82	+103	+34	+92	+62	+29	+40	+23	+28	+22	+ 30	−22
Autumn	+38	+15	+ 47	−28	+47	+33	+12	+53	+30	+ 72	+12	+102	+30
Year ...	+44	+94	+ 2	−21	+98	+31	+29	+19	+17	+100	+43	+130	+19

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TABLE I.—METEOROLOGICAL FACTORS, 1925 26—*continued.*

C. *Daily Mean Sunshine in Hours, Variations from the Average.*

MONTHS.	Mean Dis. A—J.	Chan. Islands. 11.	A. Eng. S.W 8.	B. Ire. S. 10.	C. Eng. S.E. 5.	D. Eng. Mid. 4.	E. Eng. E. 3.	F. Eng. N.W. 7.	G. Ire. N. 9.	H. Scot. W. 6.	I. Eng. N.E. 2.	J. Scot. E. 1.	K. S.
December .	+0.42	+0.23	+0.30	−0.02	+0.70	+0.32	+0.51	+0.00	+0.06	+0.62	+0.59	+0.33	−0.
January .	−0.12	−0.03	−0.15	+0.07	+0.08	−0.35	−0.22	−0.00	−0.03	−0.17	−0.14	−0.10	−0.
February .	−0.05	−0.03	−1.13	−1.25	−0.83	−0.06	−1.13	−0.83	−1.06	−1.01	−0.87	−0.41	−1.
Winter .	−0.22	−0.24	−0.30	−0.40	−0.02	−0.33	−0.28	−0.08	−0.34	−0.19	−0.14	−0.00	−0.
March .	−0.62	−0.81	−1.17	−1.13	+0.08	−0.72	+0.10	−0.58	−1.18	−0.79	−0.26	−0.52	−0.
April .	−0.75	+0.20	−0.32	+0.07	−1.43	−1.74	−1.87	−0.04	+1.10	−1.01	−1.42	−0.88	−0.
May .	−0.55	−1.28	−0.55	−0.04	−1.04	−1.10	−0.80	−0.00	−0.07	−0.53	+0.22	+0.00	−0.
Spring .	−0.64	−0.63	−0.68	−0.47	−0.80	−1.22	−0.80	−0.43	−0.25	−0.78	−0.40	−0.45	−0.
June .	−0.18	+0.05	+1.22	−0.43	−0.38	−0.42	−0.83	+0.61	−0.55	+0.46	−1.05	−0.30	−1.
July .	−0.00	−0.30	−0.40	+0.21	−0.76	−0.52	−0.65	−0.57	+0.02	+0.38	−0.16	+0.07	−1.
August .	+0.52	−0.04	−0.24	+0.12	+0.38	+0.04	+0.48	+0.53	+0.70	+0.00	+1.08	−0.80	−0.
Summer .	+0.08	−0.20	+0.19	−0.03	−0.25	−0.10	−0.33	+0.19	−0.28	+0.48	−0.04	−0.40	−0.
September .	−0.43	−1.00	−1.31	−0.70	−0.58	−0.77	−0.40	−0.51	−0.27	−0.08	+0.11	+0.31	−0.
October .	+0.44	+0.02	+0.06	+0.06	−0.12	+0.32	+0.32	+0.56	+0.62	+0.31	−0.05	+1.02	−0.
November .	−0.13	+0.03	+0.03	−0.13	−0.76	−0.26	−0.72	+0.08	−0.02	−0.03	−0.18	+0.71	−1.
Autumn .	−0.04	−0.32	−0.41	−0.26	−0.49	−0.24	−0.30	+0.04	+0.21	+0.07	+0.20	+0.08	−0.
YEAR.	−0.21	−0.35	−0.30	−0.29	−0.30	−0.47	−0.44	−0.07	−0.03	−0.11	−0.10	+0.10	−0.

(*Continued from page* 252.)

ADDITIONAL RECORDS OF PLANTS IN THE INTERNATIONAL LIST[3] (Table VIII.).—Our Tables III. and IV. include 15 of the 31 in this list. Some observers have kindly sent in records of 13 others. In the course of years such observations will be valuable. We are glad to hear that similar records are materializing in various parts of the Continent and Dominions, a good omen that in due course international phenology will be established on a firm foundation.* For the present only the mean dates appear in our table.

INSECTS (Tables IX. and X.).—As we should expect the earliness note is even more pronounced until May. As the ordinary range of each event is more restricted than with plants, though less so than with birds, the average of seven days up to the Orange Tip is fully comparable with that of flowers up to hawthorn. Thanks to the May cold the Meadow Brown event is brought back to the average. Of districts only Ireland S is late by three days. Scotland E was 19 days early with an average date only exceeded in S Britain, instead of being the latest of all. Thus it corroborates our isakair chart (Fig. 4).

(*Continued on page* 269.)

[3] Published in *Nature*, March 20, 1926.

* Since this was in type request for details has come from Taschkent, where a phenological network over Bokhara is being organised; also news that first steps to establish a network over Norway have been taken.

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TABLE I.—Meteorological Factors, 1925/26—*continued.*

D. *Accumulated Temperature "A" above and "B" below 42° F. (Day—Deg. F.), Variations from the Average.*

Months (to nearest weeks).	Mean. A—J.		Channel Islands. 11.		A. Eng. S.W. 8.		B. Ire. S. 10.		C. Eng. S.E. 5.		D. Eng. Mid. 4.		E Eng. E. 3.		F. Eng. N.W. 7.		G. Ire. N. 9		H. Scot. W. 6.		I. Eng. N E. 2.		J. Scot. E. 1.		K Scot. N. 0.	
1925-26.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Nov. 29—Jan. 3 .	— 28	+ 63	— 32	+ 6	— 34	+ 38	— 38	+ 25	— 26	+ 53	— 19	+ 72	— 18	+ 54	— 30	+ 65	— 19	+ 18	— 36	+ 105	— 26	+ 89	— 34	+ 108	— 34	+ 97
Jan. 4—Jan. 30 .	+ 10	— 36	+ 14	— 18	+ 10	— 30	+ 9	— 36	+ 15	— 19	+ 9	— 31	+ 13	— 20	+ 12	— 50	+ 18	— 47	+ 9	— 48	+ 9	— 20	— 4	— 60	+ 4	— 73
Jan. 31—Feb. 27 .	+ 47	— 69	+ 82	— 33	+ 60	— 67	+ 56	— 59	+ 67	— 88	+ 52	— 88	+ 56	— 95	+ 54	— 62	+ 42	— 56	+ 30	— 55	+ 42	— 63	+ 15	— 54	+ 22	— 67
Winter . .	+ 29	— 42	+ 64	— 37	+ 36	— 59	+ 27	— 70	+ 56	— 54	+ 42	— 47	+ 51	— 61	+ 36	— 47	+ 41	— 85	+ 3	+ 2	+ 25	+ 6	— 23	— 6	— 8	— 43
Actual Aggregates	182	291	425	45	249	173	284	136	227	259	172	381	175	348	174	260	210	176	131	314	132	391	64	476	81	361
Feb. 28—Mar. 27	+ 28	— 50	+ 28	— 18	+ 23	— 40	+ 31	— 36	+ 31	— 51	+ 25	— 59	+ 32	— 63	+ 26	— 44	+ 29	— 46	+ 30	— 46	+ 31	— 51	+ 23	— 65	+ 25	— 58
Mar. 28—May 1 .	+ 52	— 39	+ 51	— 7	+ 44	— 24	+ 44	— 28	+ 51	— 24	+ 40	— 47	+ 79	— 50	+ 65	— 42	+ 54	— 37	+ 54	— 45	+ 63	— 45	+ 24	— 51	+ 50	— 66
May 2—May 29 .	— 21	+ 6	— 7	0	— 24	+ 1	— 23	+ 3	— 29	— 2	— 21	+ 8	— 18	— 5	— 16	+ 8	— 22	+ 8	— 18	+ 13	— 9	+ 17	— 24	+ 15	— 20	+ 4
Spring . .	+ 59	— 83	+ 72	— 25	+ 43	— 63	+ 52	— 61	+ 53	— 77	+ 44	— 98	+ 93	— 118	+ 75	— 78	+ 61	— 75	+ 66	— 78	+ 85	— 79	+ 23	— 101	+ 55	— 120
Actual Aggregates	524	85	701	9	557	54	593	41	596	62	550	112	587	72	513	72	502	63	477	97	482	113	379	166	358	122
May 30—July 3 .	— 9	0	— 28	0	— 21	0	— 20	0	— 21	0	— 11	0	+ 4	0	— 6	0	— 22	0	— 7	0	+ 17	0	— 5	— 2	+ 24	— 2
July 4—July 31 .	+ 65	0	+ 52	0	+ 67	0	+ 88	0	+ 33	0	+ 66	0	+ 36	0	+ 89	0	+ 77	0	+ 70	0	+ 77	0	+ 53	0	+ 64	0
Aug. 1—Aug. 28 .	+ 36	0	+ 35	0	+ 46	0	+ 42	0	+ 19	0	+ 46	0	+ 35	0	+ 37	0	+ 39	0	+ 23	0	+ 48	0	+ 22	0	+ 41	0
Summer . .	+ 92	0	+ 59	0	+ 92	0	+ 110	0	+ 31	0	+ 101	0	+ 75	0	+ 120	0	+ 94	0	+ 86	0	+ 142	0	+ 70	— 2	+ 129	— 2
Actual Aggregates	1513	0	1689	0	1591	0	1558	0	1647	0	1597	0	1627	0	1536	0	1395	0	1382	0	1520	0	1273	0	1207	0
Aug. 29—Oct. 2 .	+ 81	— 1	+ 103	0	+ 110	0	+ 83	0	+ 103	0	+ 89	— 2	+ 110	+ 1	+ 76	0	+ 70	0	+ 60	— 1	+ 81	0	+ 27	— 3	+ 16	— 2
Oct. 3—Oct. 30 .	— 38	+ 44	— 25	0	— 35	+ 20	— 28	+ 30	— 44	+ 26	— 33	+ 48	— 32	+ 25	— 43	+ 48	— 27	+ 34	— 51	+ 69	— 35	+ 51	— 55	+ 79	— 62	+ 67
Oct. 31—Nov. 27 .	— 27	+ 5	— 16	— 3	— 24	0	— 40	+ 10	— 4	— 13	— 24	+ 6	+ 1	— 21	— 37	+ 7	— 33	+ 12	— 34	+ 23	— 29	+ 12	— 38	+ 11	— 27	+ 7
Autumn . .	+ 16	+ 45	+ 62	— 3	+ 54	+ 20	+ 15	+ 40	+ 55	+ 13	+ 32	+ 52	+ 79	+ 5	— 4	+ 55	+ 10	+ 46	— 25	+ 91	+ 17	+ 63	— 66	+ 87	— 73	+ 72
Actual Aggregates	810	108	1242	0	966	64	872	83	1001	58	805	135	934	67	787	102	753	95	678	156	768	120	545	199	511	156
Year.	+ 196	— 77	+ 257	— 65	+ 222	— 93	+ 204	— 91	+ 195	— 118	+ 219	— 93	+ 298	— 174	+ 227	— 70	+ 206	— 114	+ 130	+ 15	+ 269	— 10	+ 4	— 22	+ 103	— 93
Actual Aggregates	3029	484	4057	54	3357	291	3307	260	3471	379	3124	628	3323	487	3010	434	2860	334	2668	567	2902	624	2261	841	2157	639

The "Actual Aggregates" are the totals for the periods in question of degrees of daily mean temperature respectively above and below 42° F.

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TABLE II.—List of Stations furnishing Plant, Bird and Insect Records, with the Names of the Observers, 1926.

The numbers in brackets following the District Letters represent the Meteorological designations.

An asterisk after an Observer's name indicates a Fellow of the Royal Meteorological Society.

Station.	County.	Height above Sea-level.	Observer.
A (8).			Observers: 73 − 12 + 7 = 68.
0a. Guernsey, Les Blanches	Channel Is.	310	B. T. Rowswell.
0b. Guernsey, South Coast	Channel Is.		Miss M. A. Brock.
0d. Guernsey, Les Hubits	Channel Is.	250	W. H. Jones.
0e. Jersey, Westmount	Channel Is	150	H. T. Moore.
1a. Carbis Bay	Cornwall	100	J. F. Hosking.
1b. St. Buryan	Cornwall	200	Miss E. Westrup.
2e. Devoran	Cornwall	20	T. S. Attlee.
2f. Phillack Hayle	Cornwall	100	F. Harris.
4b. Lambourne Hill, Perranporth	Cornwall	300	Miss M. J. Rilstone.
5a. Polperro	Cornwall	100	Mr. and Mrs. Perrycoste.
5b. Polperro	Cornwall	80	F. Rilstone.
5c. Polperro	Cornwall	80	F. H. Wyatt.
5d. Bodmin	Cornwall	200	W. J. Smith.
6a. Duloe	Cornwall	440	C. S. T. Hooper.
6b. Tavistock	Devon	400	W. J. Monk.
6c. Lopwell, Plymouth	Devon		W. H. Fowler.
8b. Buckfastleigh	Devon	200	L. Williams.
9a. Launceston	Cornwall	450	Rev. T. N. H. Smith-Pearse.
9b. Hexworthy	Cornwall	270	R. B. Rogers.
9b. Clawton, Holsworthy	Devon	500	Rev. H. H. Harvey.
10b. Torquay	Devon	0	Col. W F. Cahusac.
10d. Newton Abbott	Devon	370	Ministry of Agriculture.
11d. Copplestone	Devon	300	Mr. and Mrs. J. M. Pope.
11e. Lydford, Bridestowe	Devon	800	J. M. Loveband.
13a. Exmouth	Devon	20	D. E. Civil.
13c. Exeter	Devon	100	A. H. Rousham.
14a. Umberleigh	Devon	70	Mrs. B. M. Hamilton.
14b. Bishops Tawton	Devon	50	R. Taylor.
14d. Barnstaple	Devon	200	Miss E. F. Sterry.
15a. Buckerell	Devon	300	G. T. Harris.
15b. Colyford	Devon	30	Miss A. M. Rutherfoord.
15c. Lyme Regis	Dorset	250	W. J. Harding, M.A.
17a. Combe Martin	Devon	180	J. E. Clennell.
17b. Combe Martin	Devon		A. E. Mahood, M.B.
17c. Combe Martin	Devon	300	S. Lawrence.
18a. Weymouth	Dorset	100	Mrs. N. M. Richardson.
19c. Bradney, Bridgwater	Somerset	10	C. C. D. Jarman.
19e. Ilminster	Somerset		W. P. Martin, M.A.
19f. Staplegrove, Taunton	Somerset	0	The Misses F. E. T. and E. R. Welch.
19g. West Buckland	Somerset	200	E. B. Bellamy.
20a. West Porlock	Somerset	100	N. G. Hadden.

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21c. Sturminster Marshall	Dorset	110	J. Bartlett.
21d. Broadstone	Dorset	300	Mrs. I. M. Bingham.
22a. Pulham	Dorset		Rev. J. Ridley.
22c. Street	Somerset	100	H. Underwood.
22d. Bruton	Somerset	250	E. J. Moore, M.C., B.Sc.
24a. Blandford	Dorset	100	W. Ford.
25b. Flax Bourton	Somerset	120	F. Tutin.
25c. Keynsham	Somerset	120	W. H. Stephens.
25e. Weston, Bath	Somerset	200	Miss I. Norman.
25f. Pensford	Somerset	400	H. Leybourne Popham.
25g. Butcombe	Somerset		N. C. Coombs.
27c. Portishead	Somerset	250	T. Clarke.
28b. Clevedon	Somerset	50	Miss W. G. Seeley.
28c. Cardiff	Glamorgan	0	F. J. Wright.
28d. Llandaff	Glamorgan	100	Miss C. M. Acland.
28e. St. Fagans, Llandaff	Glamorgan	130	Y. Y. Rees.
29a. Bridgend	Glamorgan	80	H. J. Randall.
30a. Mumbles, Swansea	Glamorgan	150	Miss V. Peel.
32a. Tenby	Pembroke	80	Dr. W. Howells.
32b. Tenby	Pembroke	90	F. P. Ramsden.
33a. St. Davids	Pembroke	300	Miss K. M. Green.
34c. Philadelphia	Carmarthen	380	W. J. Harries.
36a. Llandilo	Carmarthen	250	D. E. Stephens.
40a. Abergavenny	Monmouth	310	W. Baker-Gabb.
43a. Hafod, Devil's Bridge	Cardigan	580	D. H. Dunn.
43b. Aberystwyth	Cardigan	300	D. W. Davies.
43c. Aberystwyth	Cardigan	220	J. H. Salter.
B (10).			Observers: 17−3+6=20.
6a. Timoleague	Cork	30	Mrs. G. E. Lucas.
13a. Ballycotton	Cork	100	Miss A. M. Lynch.
14a. Monkstown	Cork	200	Miss E. M. Ferguson.
14b. Passage West	Cork	350	J. Mintern.*
22b. Castle Lyons, Fermoy	Cork	160	The Misses Bond.
27a. Castleconnell	Limerick	170	J. E. Austin.
30a. Cashel	Tipperary	260	E. W. Montagu Murphy.*
33a. Ballycogley, Tomhaggard	Wexford		F. Boxwell.
34b. Kilkenny	Kilkenny	220	Lady Wheeler Cuffe and M. Murray.
34c. Kilkenny	Kilkenny	170	Miss F. E. Butler.
34d. Freshford	Kilkenny	200	Miss B. Purdon.
38a. Mount Leinster, Borris	Carlow	700	Mrs. C. Butler.
38b. Borris	Carlow	280	Miss J. Kavanagh.
38c. Enniscorthy	Wexford	170	Dr. G. E. J. Greene.
42b. Rathvilly	Carlow	400	Mrs. D. M. Irwin.
42c. Ballickmoyler	Carlow		Mrs. Ffolliott.
43a. Mountmellick	Queen's Co	250	Mrs. A. E. Pim.
43b. Stradbally	Queen's Co	250	J. W. Young.
49b. Dundrum	Dublin	250	Rev. Canon Kingsmill Moore, D.D.
50a. Johnstown Bridge	Kildare	280	Miss A. M. McNally.
C (5).			Observers: 60−11+17=66.
1a. Bournemouth	Hants	120	Dr. F. G. Penrose, F.Z.S., M.B.O.U.
1e. Bournemouth West	Hants	60	Mrs. H. Bury.
1f. Boscombe	Hants	100	A. R. Gillman.
1j. Southbourne	Hants	40	C. E. Tucker.
1b. Ringwood	Hants	80	L. W. Hinxman.

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TABLE II.—List of Stations furnishing Plant, Bird and Insect Records, with the Names of the Observers, 1926—*continued.*

Station.	County.	Height above Sea-level.	Observer.
1c. Lymington	Hants	0	P. A. Ouvry.
1i. Appleslade, Ringwood	Hants	138	The Misses Haines.
1d. Totland Bay	I. of Wight	140	J. Dover.*
3a. Shanklin	I. of Wight	170	R. H. Fox.
3e. Southsea	Hants	200	Col. W. J. Gaitskell.*
3g. Newport	I. of Wight	50	J. F. Jackson.
4b. Sherfield English	Hants	200	H. Philpot.*
4c. Stratford-sub-Castle, Salisbury	Wilts	170	Miss C. L. Carpenter.
5b. Holt, Trowbridge	Wilts	150	Mrs. W. Gee.
5d. Bratton	Wilts	250	Miss H. M. Hughes.
5e. Steeple Ashton	Wilts	260	Rev. Canon E. P. Knubley.
6a. Havant	Hants	40	H. Beeston,* M.B.O.U.
6c. Chichester	Sussex	250	Miss B. Farley.
6d. Hayling Island	Hants	10	J. Staley.
6e. Hayling Island	Hants	10	E. W. F. Fowler.
7a. Botley	Hants	40	Lady Jenkyns.
7b. West Meon	Hants	470	Major and Mrs. G. E. Galbraith.*
7c. Hythe, Southampton	Hants	60	C. T. Hirst.
7f. Sutton Scotney	Hants	240	G. Abbey.
7h. Winchester	Hants	130	Miss E. M. Williams.
8b. Marlborough	Wilts	430	Marlborough College N.H.S.
10b. Hove	Sussex	160	E. J. B. Sopp.
10e. Littlehampton	Sussex	30	F. Benson.
11b. Newton Valance, Alton	Hants	600	Mrs. E. Jervoise.*
11c. Haslemere	Surrey	580	E. M. Nicholson.
13a. Swindon	Wilts	350	A. F. Smith.
14a. Seaford	Sussex	200	J. F. Thomas.
15b. Horsham	Sussex	140	H. Dinnage.
15d. Horsham	Sussex	170	Mrs. T. Faulkner Jefferis.
15c. Steyning	Sussex	70	C. M. Woodford.
16b. Farnham	Surrey	200	Mrs. H. M. Gohery.
16f. Odiham	Hants	350	Mrs. W. M. E. Fowler.
16g. Rowledge, Farnham	Surrey	360	Miss H. E. Harke.
16i. Churt, Farnham	Surrey	300	Lieut.-Col. C. H. Ward.
16m. Godalming	Surrey	330	Miss A. L. Nix.
18a. Lewes	Sussex	50	R. Morris.
18b. Hellingly	Sussex	210	Mrs. M. Stroud.
18c. Ditchling	Sussex	230	F. F. Wood.
19a. Cranleigh	Surrey	90	Miss Ravenscroft.
20a. Reading	Berks		I. Clarke
20c. Maidenhead	Berks		Miss M. Gardner.
21b. Hastings	Sussex		H. G. Attlee.
21c. Burwash	Sussex	280	Lieut.-Col. J. E. H. Sawyer.
21d. Rye	Sussex	70	Miss E. Johnson.
22a. Lingfield	Surrey	270	Mrs. Margary.
22b. Warlingham	Surrey		A. Beadell.
22c. Purley	Surrey	350	J. E. Clark,* B.A., B.Sc., and friends.
22e. Limpsfield	Surrey		G. Hesilrige, F.R.G.S.
22f. Penshurst	Kent	130	Miss D. M. Diamond.
24a. Lympne	Kent	350	J. G. Goodyear.*
24b. Woodchurch	Kent	100	W. R. Marchant.
25a. Maidstone	Kent	100	H. Elgar.
25b. Mereworth	Kent	150	Miss M. E. Bunyard.

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25d. East Malling	Kent	130	Ministry of Agriculture.
26a. Bromley	Kent	170	J. B. Dalton.
26d. Sydenham	Kent	250	Miss J. B. Chambers.
26f. Anerley	Kent		J. H. Aylwin.
27a. Whitstable	Kent	160	H. Court.
28a. Rochester	Kent	100	Mrs. H. M. Rait Kerr.
29a. Ash, Sandwich	Kent	50	Miss Tower and Girl Guide Co.
29b. Sandwich	Kent	0	Miss E. Day.
D (4).			Observers: 64−17+11=58.
3b. Ross	Hereford	210	Miss M. L. Southall.
3d. Longhope	Gloucester	250	Miss F. M. Heward.
4a. Weobley	Hereford	320	Miss M. Hall.*
4b. Staunton-on-Arrow	Hereford	400	Rev. Preb. S. Cornish Watkins.
5a. Cirencester	Gloucester	450	W. H. Leach.
5d. Coaley	Gloucester	300	A. D. Norton.
5e. Churchdown	Gloucester	300	J. M. Purnell.
5f. Cheltenham	Gloucester	220	Cheltenham College N.H.S.
6a. Dymock	Gloucester	120	Miss M. Peake.
6b. Bromyard	Hereford	400	Miss M. A. Philpott.
6c. Grantsfield, Leominster	Hereford	400	Miss Hutchinson.
6d. Colwall, Malvern	Hereford	500	F. M. Day.
10b. Evesham	Worcester	150	R. Gibbins.
10c. Ashorne	Warwick	160	G. T. Osborn.*
11a. Tenbury	Worcester	310	Frederick Lowe.
14a. Oxford	Oxford	110	W. H. Piper.
14b. Oxford	Oxford	210	F. A. Bellamy, M.A., F.R.A.S.
15a. Whernalls, Alcester	Warwick	230	E. W. and R. H. R. Jephcott.
15c. Stratford-on-Avon	Warwick	190	F. G. Savage.
16b. Cookley, Wolverly	Worcester	250	T. J. Beeston.
16c. Barnt Green, Birmingham	Worcester	650	Miss M. Gibbins.
16e. South Birmingham	Warwick	500	H. G. Alexander.
16f. Frankley, Birmingham	Worcester	580	W. H. Sisman.
17a. Edgmond, Newport	Shropshire	220	D. H. Robinson.
18a. Trefonen, Oswestry	Shropshire	600	N. W. Thomas.
18b. Oswestry	Shropshire	430	C. H. W. Pugh.
18c. Gobowen, Oswestry	Shropshire		Miss E. R. Lloyd.
19b. Granborough	Bucks	300	Rev. C. E. Martin.
19d. Weston Turville	Bucks	320	G. Eland.
20a. Farnborough	Warwick	520	Miss C. Prater, A.R.R.C.
21b. Erdington	Warwick	420	E. W. Moore, B.Sc., A.I.C.
21d. Hampton-on-the-Hill	Warwick	200	J. L. Hodgkinson.
21h. Leamington	Warwick	200	Miss J. M. Reynolds.
22a. Wolverhampton	Stafford	500	Mrs. J. Berrington.
24a. Bletchley	Bucks	330	A. S. King.
24b. Northampton	Northants	250	H. N. Dixon and W. N. Mold.
26b. Sutton Coldfield	Warwick	410	Miss B. A. Carter.
28a. Harrowden, Wellingborough	Northants	300	J. Hall.
30a. Mayfield Ashbourne	Derbyshire	420	F. H. Wright.
30e. Farley, Alton	Staffs		E. S. Pickard.
33a. Ketton	Rutland	290	Rev. A. H. Snowden.

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TABLE II.—List of Stations furnishing Plant, Bird and Insect Records, with the Names of the Observers, 1926—*continued.*

Station.	County.	Height above Sea-level.	Observer.
1c. Lymington	Hants	0	P. A. Ouvry.
1i. Appleslade, Ringwood	Hants	138	The Misses Haines.
1d. Totland Bay	I. of Wight	140	J. Dover.*
3a. Shanklin	I. of Wight	170	R. H. Fox.
3e. Southsea	Hants	200	Col. W. J. Gaitskell.*
3g. Newport	I. of Wight	50	J. F. Jackson.
4b. Sherfield English	Hants	200	H. Philpot.*
4c. Stratford-sub-Castle, Salisbury	Wilts	170	Miss C. L. Carpenter.
5b. Holt, Trowbridge	Wilts	150	Mrs. W. Gee.
5d. Bratton	Wilts	250	Miss H. M. Hughes.
5e. Steeple Ashton	Wilts	260	Rev. Canon E. P. Knubley.
6a. Havant	Hants	40	H. Beeston,* M.B.O.U.
6c. Chichester	Sussex	250	Miss B. Farley.
6d. Hayling Island	Hants	10	J. Staley.
6e. Hayling Island	Hants	10	E. W. F. Fowler.
7a. Botley	Hants	40	Lady Jenkyns.
7b. West Meon	Hants	470	Major and Mrs. G. E. Galbraith.*
7c. Hythe, Southampton	Hants	60	C. T. Hirst.
7f. Sutton Scotney	Hants	240	G. Abbey.
7h. Winchester	Hants	130	Miss E. M. Williams.
8b. Marlborough	Wilts	430	Marlborough College N.H.S.
10b. Hove	Sussex	160	E. J. B. Sopp.
10e. Littlehampton	Sussex	30	T. Benson.
11b. Newton Valance, Alton	Hants	600	Mrs. E. Jervoise.*
11c. Haslemere	Surrey	580	E. M. Nicholson.
13a. Swindon	Wilts	350	A. F. Smith.
14a. Seaford	Sussex	200	J. F. Thomas.
15b. Horsham	Sussex	140	H. Dinnage.
15d. Horsham	Sussex	170	Mrs. T. Faulkner Jefferis.
15c. Steyning	Sussex	70	C. M. Woodford.
16b. Farnham	Surrey	200	Mrs. H. M. Gohery.
16f. Odiham	Hants	350	Mrs. W. M. E. Fowler.
16g. Rowledge, Farnham	Surrey	360	Miss H. E. Harke.
16i. Churt, Farnham	Surrey	300	Lieut.-Col. C. H. Ward.
16m. Godalming	Surrey	330	Miss A. L. Nix.
18a. Lewes	Sussex	50	R. Morris.
18b. Hellingly	Sussex	210	Mrs. M. Stroud.
18c. Ditchling	Sussex	230	F. F. Wood.
19a. Cranleigh	Surrey	90	Miss Ravenscroft.
20a. Reading	Berks		I. Clarke
20c. Maidenhead	Berks		Miss M. Gardner.
21b. Hastings	Sussex		H. G. Attlee.
21c. Burwash	Sussex	280	Lieut.-Col. J. E. H. Sawyer.
21d. Rye	Sussex	70	Miss E. Johnson.
22a. Lingfield	Surrey	270	Mrs. Margary.
22b. Warlingham	Surrey		A. Beadell.
22c. Purley	Surrey	350	J. E. Clark,* B.A., B.Sc., and friends.
22e. Limpsfield	Surrey		G. Hesilrige, F.R.G.S.
22f. Penshurst	Kent	130	Miss D. M. Diamond.
24a. Lympne	Kent	350	J. G. Goodyear.*
24b. Woodchurch	Kent	100	W. R. Marchant.
25a. Maidstone	Kent	100	H. Elgar.
25b. Mereworth	Kent	150	Miss M. E. Bunyard.

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25d. East Malling	Kent	130	Ministry of Agriculture.
26a. Bromley	Kent	170	J. B. Dalton.
26d. Sydenham	Kent	250	Miss J. B. Chambers.
26f. Anerley	Kent		J. H. Aylwin.
27a. Whitstable	Kent	160	H. Court.
28a. Rochester	Kent	100	Mrs. H. M. Rait Kerr.
29a. Ash, Sandwich	Kent	50	Miss Tower and Girl Guide Co.
29b. Sandwich	Kent	0	Miss E. Day.
D (4).			Observers: 64−17+11=58.
3b. Ross	Hereford	210	Miss M. L. Southall.
3d. Longhope	Gloucester	250	Miss F. M. Heward.
4a. Weobley	Hereford	320	Miss M. Hall.*
4b. Staunton-on-Arrow	Hereford	400	Rev. Preb. S. Cornish Watkins.
5a. Cirencester	Gloucester	450	W. H. Leach.
5d. Coaley	Gloucester	300	A. D. Norton.
5e. Churchdown	Gloucester	300	J. M. Purnell.
5f. Cheltenham	Gloucester	220	Cheltenham College N.H.S.
6a. Dymock	Gloucester	120	Miss M. Peake.
6b. Bromyard	Hereford	400	Miss M. A. Philpott.
6c. Grantsfield, Leominster	Hereford	400	Miss Hutchinson.
6d. Colwall, Malvern	Hereford	500	F. M. Day.
10b. Evesham	Worcester	150	R. Gibbins.
10c. Ashorne	Warwick	160	G. T. Osborn.*
11a. Tenbury	Worcester	310	Frederick Lowe.
14a. Oxford	Oxford	110	W. H. Piper.
14b. Oxford	Oxford	210	F. A. Bellamy, M.A., F.R.A.S.
15a. Whernalls, Alcester	Warwick	230	E. W. and R. H. R. Jephcott.
15c. Stratford-on-Avon	Warwick	190	F. G. Savage.
16b. Cookley, Wolverly	Worcester	250	T. J. Beeston.
16c. Barnt Green, Birmingham	Worcester	650	Miss M. Gibbins.
16e. South Birmingham	Warwick	500	H. G. Alexander.
16f. Frankley, Birmingham	Worcester	580	W. H. Sisman.
17a. Edgmond, Newport	Shropshire	220	D. H. Robinson.
18a. Trefonen, Oswestry	Shropshire	600	N. W. Thomas.
18b. Oswestry	Shropshire	430	C. H. W. Pugh.
18c. Gobowen, Oswestry	Shropshire		Miss E. R. Lloyd.
19b. Granborough	Bucks	300	Rev. C. E. Martin.
19d. Weston Turville	Bucks	320	G. Eland.
20a. Farnborough	Warwick	520	Miss C. Prater, A.R.R.C.
21b. Erdington	Warwick	420	E. W. Moore, B.Sc., A.I.C.
21d. Hampton-on-the-Hill	Warwick	200	J. L. Hodgkinson.
21h. Leamington	Warwick	200	Miss J. M. Reynolds.
22a. Wolverhampton	Stafford	500	Mrs. J. Berrington.
24a. Bletchley	Bucks	330	A. S. King.
24b. Northampton	Northants	250	H. N. Dixon and W. N. Mold.
26b. Sutton Coldfield	Warwick	410	Miss B. A. Carter.
28a. Harrowden, Wellingborough	Northants	300	J. Hall.
30a. Mayfield Ashbourne	Derbyshire	420	F. H. Wright.
30e. Farley, Alton	Staffs		E. S. Pickard.
33a. Ketton	Rutland	290	Rev. A. H. Snowden.

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TABLE II.—List of Stations furnishing Plant, Bird and Insect Records, with the Names of the Observers, 1926—*continued*.

Station.	County.	Height above Sea-level.	Observer.
34a. Kegworth	Leicester	200	A. Roebuck.
35a. Somershal Herbert	Derbyshire	320	N. H. FitzHerbert.
35b. Matlock	Derbyshire	550	T. B. Franklin.*
38a. Hodsock	Notts	60	Miss Mellish.
39a. Huddersfield	Yorks W.R.	330	C. Mosley, M.B.O.U.
39b. Kirkheaton	Yorks W.R.	250	E. Fisher.
39c. Thurlstone, Penistone	Yorks W.R.	770	H. Staniforth.*
39d. Sheffield	Yorks W.R.	500	A. Thompson.
41b. Wilsden	Yorks W.R.	700	E. P. Butterfield.
41d. Crosshills, Keighley	Yorks W.R.	350	J. Holmes.
44a. Sitwell Vale	Yorks W.R.	300	G. Howard.
44b. Newhill, Wath	Yorks W.R.	230	J. H. Payne.
44e. Harlington, Mexborough	Yorks W.R.	80	Miss M. A. Brown.
45a. Overton, Wakefield	Yorks W.R.	420	J. Hooper.
45b. Altofts, Normanton	Yorks W.R.	120	H. G. Townsend.
49a. Red Hill, Castleford	Yorks W.R.	230	H. England.
49b. Fairburn, Ferrybridge	Yorks W.R.	120	W. G. Bramley.
E (3).			Observers: 38 − 6 + 13 = 45.
1b. New Barnet	Herts	200	A. V. Daniels.
1c. Barnet	Herts	440	L. R. Woolner.
1d. Whetstone	Herts	300	M. T. E. Millington.
1f. New Barnet	Herts		J. Faulkner.
2a. Berkhamsted	Herts	400	Mrs. Mawley.
2b. Tring	Herts	450	T. G. Dale.
4b. Knebworth	Herts	300	Class II. Scholars, Council School.
4c. Harpenden	Herts	400	Miss S. Salisbury.
4l. Harpenden	Herts	350	A. H. Meiklejohn.
4h. Hitchin	Herts	250	R. Morse, F.L.S.
4i. Hitchin	Herts	270	Dr. A. H. Foster, M.B.O.U., F.E.S.
4j. Welwyn	Herts	500	Miss E. Palliser.
4k. Pirton, Hitchin	Herts	230	J. E. Thrussell.
4m. Luton	Bedfords	400	H. Cole.
5a. Turvey	Bedfords	220	A. W. Previté.
7a. Birch Green	Herts	240	F. Rayment.
7b. Sawbridgeworth	Herts	350	H. S. Rivers.
7g. Harlow	Essex		J. N. Kirkcaldy.
8a. Letchworth	Herts	320	W. P. Westell, F.L.S., F.S.A. (Scot.).
8b. Letchworth	Herts	300	R. Palmer, F.E.S., F.Z.S.
8c. Letchworth	Herts	290	J. H. Haysman and scholars.
8e. Kempston	Bedfords	130	R. E. Francis.
8f. Kempston	Bedfords	130	Mrs. B. F. Haylock.
10b. Halstead	Essex	140	F. N. Adams and A. Kidd.
10e. Braintree	Essex	220	H. J. Cunnington.
10f. Great Totham	Essex	200	T. Hammond.
11d. Cambridge	Cambridge	30	Miss S. Mills.
11e. Cambridge	Cambridge	80	Ministry of Agriculture.
13a. Lexden	Essex	90	S. F. Hurnard.
14a. Ballingdon, Sudbury	Essex	150	C. F. D. Sperling.
14b. Belchamp Otten	Essex	250	H. P. Parmenter.

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14c. Sudbury	Suffolk	100	E. W. Robinson.
17b. Ipswich	Suffolk	150	A. G. and W. J. Glenn.
17e. Boxford†	Suffolk		Mrs. G. B. Andrew.
17f. Finborough, Stowmarket	Suffolk	160	C. Pettiward.
22b. Langford, Watton	Norfolk	60	A. H. Turner.*
22c. Methwold, Brandon	Norfolk	40	Rev. H. R. Didcock.
22d. Grimston, Lynn	Norfolk	50	J. R. Steward and scholars.
23c. Framlingham	Suffolk		F. K. Staunton.
24a. Norwich	Norfolk	100	A. W. Preston.*
24b. Postwick, Norwich	Norfolk	100	Mrs. E. M. Parry.
25a. Hunstanton	Norfolk	50	Miss F. E. Johnson.
27a. Hevingham	Norfolk	90	Major H. S. Marsham.
27c. Cromer	Norfolk	100	Mrs. G. Hoare.
28b. Ingham, Stalham	Norfolk	30	R. Gurney.
F (7).			Observers: 28−5+2=25.
9a. Beaumaris	Anglesey	160	Miss E. Ridsdale.
9b. Deganwy	Carnarvon	100	R. Jones.
10a. Wrexham	Denbighshire	300	Miss H. Jackson, B.Sc.
11d. Trefnant	Denbighshire	150	Major W. M. Congreve, M.C.
11e. Dolben, St. Asaph	Denbighshire	200	Miss B. Allen.
13c. Higher Tranmere	Cheshire	110	Mrs. F. M. Dallman.
13d. Shotwick	Cheshire	50	Mrs. E. F. A. Wansbrough.
14a. Barnton, Northwich	Cheshire	170	G. Owen.*
14b. Altrincham	Cheshire	100	Altrincham and District N.H. and L.S.
16a. Prestbury	Cheshire	450	Miss M. E. Charlton.
16b. Bramhall	Cheshire	300	C. Horton-Smith.
16c. Cheadle Hulme	Cheshire	200	J. W. Hartley.
18a. Blackpool	Lancs	0	E. C. Thatcher.
19a. Stockport	Cheshire		H. Russell.
21a. Leyland	Lancs	130	H. Nowell ffarington.*
21c. Mitton, Whalley	Lancs		Miss M. E. Ackerley.
22a. Urswick, Ulverston	Lancs	150	J. Dobson.
22b. Ulverston	Lancs	100	H. B. Turney.
22d. Grange-over-Sands	Lancs	50	Dr. R. C. Lowther.
25a. Ambleside	Westmor.	140	A. Astley, M.B.O.U.
25b. Ambleside	Westmor.	220	Miss A. C. Drury.
25c. Windermere	Westmor.	300	A. B. Reynolds.
28a. Keswick	Cumber.	250	J. Glaisyer.*
28b. Johnby Hall, Greystoke	Cumber.	800	Mrs. F. L. Leybourne Popham.
28c. Mungrisdale, Penrith	Cumber.	900	Miss L. W. Streatfield.
G (9).			Observers: 18−4+3=17.
18a. Farragh, Longford	Longford	210	Mrs. W. J. Bond.
32b. Levally, Enniskillen	Fermanagh	280	Rev. W. B. Steele.
35c. Warrenpoint	Down	190	J. Nugent.
35d. Rostrevor	Down	0	Rev. W. F. Johnson.
41a. Bessbrook	Armagh	250	S. E. Baillie.
45a. Saintfield	Down	300	Rev. E. H. Blackwood-Price.
45b. Dundrum	Down	0	Rev. W. F. Johnson.

† Previously described as 13b, Colchester (its post-town).

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TABLE II.—List of Stations furnishing Plant, Bird and Insect Records, with the Names of the Observers, 1926—*continued.*

Station.	County.	Height above Sea-level.	Observer.
47a. Sixtowns, Draperstown	Londonderry	400	G. Barnett.
48b. Altnafoyle	Londonderry	420	Mrs. C. Lamb.
50a. Hillsborough	Down	250	N. H. Foster, F.L.S.
50c. Belfast	Antrim	200	T. McCloy.
50d. Muckamore	Antrim	110	J. Marchbank.
50f. Woodbourne, Belfast	Antrim		Miss N. M. G. Neill.
51a. Magherafelt	Londonderry	200	Sister M. Borromeo Corbett.
53a. Bangor	Down		E. G. Ingold.
54a. Hazelbank, Broughshane	Antrim	450	R. J. Craig.*
54b. Larne	Antrim	0	Miss M. L. Belford.
H (6).			Observers: 6−1+3=8.
0a. Douglas	I. of Man	100	Lieut.-Col. H. W. Madoc, C.B.E., M.V.O.
0b. Castletown	I. of Man	0	P. G. Ralfe.
0c. Ramsey	I. of Man	50	T. H. Graves.
1a. Drummore, Kirkmaiden	Wigtown	100	Rev. D. R. Williamson.
2a. Marks, Creetown	Kirkcudbr't	380	Mrs. G. Williams.
12a. Moniaive	Dumfries	350	J. Corrie, F.S.A. (Scot.).
33a. Ledaig	Argyll	50	F. S. and N. H. Bethune.
33b. Kinlochleven	Argyll	0	W. B. C. Perrycoste.
I (2).			Observers: 36−4+6=38.
6a. Lincoln	Lincoln	100	E. Searson.
8a. Woodhall Spa	Lincoln	60	W. M. Myddelton.
9a. Ashby, Scunthorpe	Lincoln	100	A. King, F.R.A.S. and scholars.
9b. East Stockwith, Gainsborough	Lincoln	20	H. Maw.
10a. West Keal	Lincoln	200	Miss E. M. Grantham.
11b. Thornton Abbey	Lincoln	30	J. H. Davey.
11c. Weelsby, Grimsby	Lincoln	30	S. A. Cox.
11d. Cleethorpes	Lincoln	40	Miss A. F. Oddy, M.Sc.
12a. Holderness	Yorks E.R.	200	E. W. Wade (North Ferriby).
13a. Osgodby, Selby	Yorks E.R.	30	J. W. Eves.
14a. York	Yorks E.R.	80	S. H. Smith, F.Z.S. and others.
14b. York	Yorks E.R.		J. A. G. Barnes.
18a. Middleton-in-Teesdale	Durham	800	J. J. Parker.
19a. Haltwhistle	Northumb.	900	M. Philipson.
20a. Louth	Lincoln	170	C. S. Carter.
21a. Hull	Yorks E.R.		C. E. Jacklin.*
23a. Thirsk	Yorks N.R.	120	A. B. Hall.
24b. Darlington	Durham	170	Darlington and Teesdale Nat. F.C.
25a. Corbridge-on-Tyne	Northumb.	300	A. W. Price.
25c. Corbridge-on-Tyne	Northumb.	500	R. B. Cooke.
25e. Corbridge-on-Tyne	Northumb.		The late J. G. Black.

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25b. Stocksfield-on-Tyne	Northumb.	300	H. Walton.
25d. Allendale	Northumb	800	G. Stephenson.
26a. Catcleugh, Upper Redesdale	Northumb.	840	R. Craig.
27a. Withernsea	Yorks E.R.	10	Rev. C. Binns.
29b. Scalby, Scarborough	Yorks E.R.	100	W. W. Nettleton.
33a. Lanchester	Durham	400	E. A. Leigh, B.Sc.
33b. Chopwell	Durham	500	P. Charlton.
33c. Chester-le-Street	Durham		J. Baxter.
33d. Springwell, Gateshead	Durham	550	G. H. Anderson.
33e. South Shields	Durham	10	W. Bennett.
33f. North Shields	Northumb.	100	J. S. Spence.
36a. Seaton Delaval	Northumb.	100	C. C. Boll.
36b. Cockle Park, Morpeth	Northumb.	320	Ministry of Agriculture.
38a. Falloden, Embleton	Northumb.	100	H. B. Herbert.
38b. Waren, Belford	Northumb.	0	T. B. Short.
38c. Lemmington, Alnwick	Northumb.	620	F. E. Lupton.*
39a. Berwick	Northumb.	50	J. B. Duncan.

J (1).

Observers: 17−2+5=20.

2a. Broughton	Peebles	630	R. J. Hogg.
4a. Selkirk	Selkirk	500	J. R. Simpson.
6a. Gattonside, Melrose	Roxburgh	310	J. Clapperton.
6b. Jedburgh	Roxburgh	220	Miss A. M. Murray.
10a. West Foulden	Berwick	250	J. H. Craw.
13a. Stirling	Stirling	200	Miss D. H. Dundas.
13c. Gargunnock	Stirling	90	J. Taylor.
15a. Dunfermline	Fife	400	N. M. Johnson, B.Sc., L.C.P., F.R.S.G.S.
20a. Loch Tummel	Perth	500	D. MacIntyre.
21a. Dundee	Forfar	200	J. Garriock, M.A., B.Sc.
21b. East Downiemount, Tayport	Fife	100	T. White, F.F.S., F.S.I.
36a. Cabrach, Huntly	Banff	1260	A. Rattray.
36b. Aberlour	Banff	350	J. G. White.
38a. Murtle, Aberdeen	Aberdeen	240	Miss F. Hamilton.
39a. Dunlugas, Turriff	Banff	100	D. Wyness.
39b. Forglen, Turriff	Banff	200	G. Stuart.
39c. Huntly	Aberdeen	400	Miss M. Wilson.
40a. Cullen	Banff	0	Miss J. Gowan.
40b. Kellas, Elgin	Elgin	450	Mrs. G. Christie.
42b. Fordyce, Portsoy	Banff	230	G. J. Milne.

K (0).

Observers: 5−0+3=8.

5a. Vallay, Lochmaddy	N. Uist	150	G. Beveridge.
24b. Muir of Ord	Ross	200	Col. A. F. Mackenzie.
24c. Muir of Ord	Ross	110	N. Fowler.
24d. Kiltarlity, Beauly	Inverness	610	D. Ross.
25a. Dundonnell, Ullapool	Ross	100	P. McRae.
26a. Aviemore	Inverness	730	Mrs. Seton Gordon.
27b. Kirkhill	Inverness	450	Mrs. Baird Ferguson*
33a. Golspie	Sutherland	100	E. W. Read.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926.
(For Latin names see Table V.).

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's-bit Scabious.	
A. Channel Isles, Guernsey,															
0a. Les Blanches	109	*27*	*41*	66	66	106	102	95	*133*	151	*163*	*185*	175	...	
0d. Les Hubits .	120	31	*49*	*73*	79	*110*	130	109	*141*	153	189	*199*	186	...	
A (8)															
4b. Lambourne Hill .	113	*32*	37	67	74	*103*	114	106	140	145	*161*	*189*	*181*	212	
5a/b. Polperro .	112	31	43	62	57	102	105	108	138	150	102	*192*	180	...	
5d. Bodmin .	111	25	27	61	61	98	110	114	*142*	149	*168*	*193*	*185*	...	
6a. Duloe . .	110	8	31	52	61	88	131	113	144	153	173	*192*	170	231	
6c. Lopwell .	123	47	59	80	66	87	119	136	157	157	185	*201*	185	...	
9a. Launceston .	121	32	48	*75*	78	95	125	113	142	158	189	*205*	*188*	...	
9c. Clawton .	126	33	*54*	*78*	79	110	124	123	162	158	188	*209*	193	...	
10d. Newton Abbot .	122	33	53	*71*	74	87	121	122	157	152	*182*	*207*	*200*	...	
11d. Copplestone .	121	35	35	*65*	70	87	140	118	*156*	156	*184*	*209*	*201*	...	
13a. Exmouth .	114	28	45	60	66	80	115	108	146	142	183	*205*	195	...	
14b. Bishop's Tawton	113	24	52	66	59	88	110	109	146	149	165	*194*	190	217	
15a. Buckerell .	123	48	*53*	*70*	77	93	124	123	*159*	161	171	*200*	190	...	
15c. Lyme Regis .	119	28	40	66	64	103	*117*	123	*152*	156	*182*	*203*	192	...	
17* Combe Martin	115	21	46	*65*	77	96	104	110	157	150	175	*194*	187	222	
18a. Weymouth	120	*15*	*39*	63	75	117	*119*	113	153	157	*181*	202	202	...	
19f. Staplegrove .	114	*25*	53	70	70	87	108	108	138	151	*166*	*196*	*195*	...	
20a. West Porlock	105	27	*41*	46	64	96	*98*	98	*135*	132	*160*	*183*	*181*	...	
21c. Sturminster Marshall	120	32	58	72	71	97	124	113	*151*	*152*	*177*	*198*	*195*	...	
21d. Broadstone .	125	35	*66*	87	96	*114*	108	119	155	142	186	194	*192*	...	
22c. Street .	133	36	67	88	88	123	*130*	137	*160*	*170*	*190*	*205*	*203*	...	
22d. Bruton .	120	12	51	*83*	91	101	124	117	145	158	166	199	*195*	224	
25b. Flax Bourton .	109	3	42	62	57	101	110	111	126	145	164	192	193	199	
25c. Keynsham .	121	36	65	74	73	101	115	112	142	160	182	*200*	186	220	
25f. Pensford .	123	23	*57*	63	71	113	119	119	152	154	196	*205*	*202*	...	
27c. Portishead .	110	9	51	56	76	104	117	114	136	135	158	185	176	218	
28b. Clevedon .	111	27	58	*63*	71	100	107	118	*137*	140	161	*186*	167	...	
28c. Cardiff .	123	31	51	73	87	122	116	114	*146*	*155*	*182*	*207*	*190*	...	
28e. St. Fagans .	127	*43*	73	69	94	108	111	121	150	150	193	*210*	201	228	
29a. Bridgend .	120	34	50	65	88	105	113	122	144	162	174	206	181	216	
30a. Mumbles .	116	32	40	60	88	100	105	119	133	159	173	*202*	*185*	217	
32a/b. Tenby .	116	34	51	71	69	103	119	117	129	163	167	*196*	173	...	
33a. St. Davids .	117	*21*	33	*56*	*59*	*94*	114	121	129	171	*195*	*207*	205	205	
34c. Philadelphia .	119	20	60	68	74	103	110	119	137	158	186	*204*	187	...	
40a. Abergavenny	121	41	56	60	85	101	115	115	132	*161*	*187*	*202*	*193*	...	
43a. Hafod .	133	43	67	104	86	*115*	127	118	167	170	*193*	206	*195*	...	
43b/c. Aberystwyth	111	26	39	62	76	104	108	108	132	150	171	187	172	...	
B (10)															
6a. Timoleague .	113	33	33	44	65	*101*	109	120	129	155	181	*188*	199	218	
14a. Monkstown .	124	35	*54*	*64*	91	*112*	126	132	*139*	147	*189*	*196*	*206*	...	

* Combination of the three stations 17a, b, d.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926—*continued.*

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's-Bit Scabious.	Ivy.
b. Passage West	124	36	*53*	*63*	75	*105*	107	124	149	162	198	*204*	214	...	246
b. Castle Lyons	116	40	40	59	*65*	*100*	107	*115*	137	154	190	190	196	221	246
a. Castleconnell	118	30	55	56	*65*	99	104	113	150	157	181	*198*	206	211	260
a. Cashel	127	*43*	*65*	58	80	*107*	118	125	152	166	202	*204*	213	225	266
b. Kilkenny	120	22	*44*	62	66	101	112	118	153	*160*	193	*199*	*208*	221	270
d. Freshford	128	51	*60*	*77*	71	*110*	122	124	*158*	161	*193*	*199*	*209*	...	...
a. Mt. Leinster.	132	*50*	73	83	86	*115*	127	125	*158*	171	200	*198*	*202*	...	275
b. Borris	116	*25*	*43*	45	75	103	117	117	135	163	197	*187*	180	...	270
c. Enniscorthy	134	51	71	*81*	100	*120*	*130*	141	152	165	193	*196*	205	...	283
a. Mountmellick	117	34	49	64	66	97	109	117	*151*	150	180	*186*	198	210	263
b. Dundrum	119	*32*	*49*	65	*73*	*103*	109	115	150	155	*191*	*189*	*192*	...	...
a. Johnstown Bridge	123	*40*	*56*	*64*	74	*110*	129	112	155	158	*195*	*193*	*196*	232	279
C (5)															
*. Bournemouth	119	35	*40*	84	*76*	102	114	123	135	152	*170*	183	*200*	...	274
j. Southbourne.	117	38	39	84	75	101	116	110	140	149	168	194	188	...	259
b. Ringwood	116	29	*40*	86	74	98	114	110	133	161	176	191	181	...	268
c. Lymington	115	38	50	94	74	99	112	117	123	147	174	161	185	220	266
i. Appleslade	119	33	61	*90*	75	99	113	113	130	151	*175*	188	194	222	276
3a. Shanklin	115	28	50	85	74	101	110	107	119	148	171	*200*	191	...	273
3e. Southsea	115	26	57	68	71	90	116	121	124	152	174	201	184	228	267
3g. Newport	114	22	39	75	75	75	*115*	139	139	142	177	185	*185*	...	263
4b. Sherfield English	114	32	56	58	67	94	110	119	141	*150*	172	184	185	207	271
c. Salisbury	121	43	*65*	*77*	76	104	112	112	148	155	184	197	184	220	267
d. Bratton	121	8	56	96	84	103	119	119	154	147	171	199	201	...	264
e. Steeple Ashton	123	38	53	74	86	93	128	116	*150*	156	179	*200*	*200*	...	...
5c. Chichester	118	33	54	56	66	97	113	108	153	156	181	201	198	232	270
5d/e. Hayling Island	115	27	45	*56*	71	91	119	114	140	155	191	*193*	179	...	275
6a. Botley	113	6	55	59	67	100	109	118	134	145	173	*193*	197	...	268
6b. West Meon	120	38	*55*	61	84	102	119	126	*148*	155	171	*193*	197	...	250
7c. Hythe	127	29	*60*	82	88	124	131	*130*	143	160	181	186	206	224	289
7h. Winchester	117	*30*	64	69	72	105	111	110	*140*	147	*165*	*193*	*192*	214	...
8b. Marlborough	121	31	66	59	67	120	120	120	142	154	177	197	196	...	264
9b. Hove	120	*33*	57	*70*	91	105	111	120	137	157	169	*193*	192	...	...
9e. Littlehampton	125	35	*58*	83	96	104	135	123	*150*	167	*176*	185	*192*	...	...
10b. Newton Valance	120	35	59	58	77	97	124	128	146	151	187	*193*	184	...	264
13a. Swindon	122	*35*	52	80	101	93	121	121	143	150	181	190	193	...	...
13b/d. Horsham	116	36	52	65	66	100	115	112	139	149	180	196	182	213	271
15b. Farnham	113	12	56	*61*	73	89	125	105	145	146	159	*200*	187	...	276
15f. Odiham	116	8	56	62	75	112	118	118	132	146	161	201	198	231	269
15g. Rowledge	118	33	32	67	*78*	100	116	119	135	157	164	198	200	...	...
15i. Churt	121	30	*55*	77	87	99	122	121	140	145	175	*198*	*200*	...	257
15m. Godalming	124	37	67	*76*	86	101	115	118	149	160	183	*198*	*200*	...	270
18a. Lewes	112	30	37	61	61	95	105	108	133	*154*	161	198	*200*	226	247
18c. Ditchling	121	48	52	79	80	93	122	119	132	156	163	201	201	246	264
19a. Cranleigh	125	43	*44*	70	78	113	124	125	155	150	190	199	196	...	...
20a. Reading	116	40	37	74	70	99	116	110	124	155	166	*200*	200	240	261

* Combination of the three stations 1a, e, f.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926—*continued.*

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's Bit Scabious.	
21d. Rye	115	22	44	67	86	75	111	110	143	155	185	*193*	184	227	
22a. Lingfield	116	6	51	59	84	86	112	132	153	151	171	185	204	221	
22c. Purley	115	24	37	65	64	98	117	108	145	147	*175*	196	*200*	225	
22f. Penshurst	121	45	55	60	*65*	106	116	138	138	158	*175*	*196*	*200*	...	
25a. Maidstone	113	10	44	66	*78*	92	108	104	140	*157*	*170*	*193*	196	...	
25b. Mereworth	113	27	36	58	72	94	122	100	137	156	169	*193*	192	223	
25d. East Malling	121	43	48	*65*	88	119	116	109	142	156	*175*	*193*	202	...	
26a. Bromley	118	*20*	*40*	73	76	98	118	109	144	165	*175*	*193*	*200*	...	
26d. Sydenham	117	7	46	66	*98*	103	103	*108*	*145*	160	*175*	*193*	202	...	
29b. Sandwich	112	30	39	59	61	100	102	104	133	144	188	205	182	...	
D (4)															
4a. Weobley	114	6	45	*70*	77	*103*	105	109	153	145	171	*193*	*193*	238	
4b. Staunton-on-Arrow	119	28	56	*70*	73	93	112	114	*155*	150	*172*	201	199	...	
5d. Coaley	117	11	64	70	*78*	99	121	105	154	149	173	182	195	211	
6a. Dymock	117	28	*54*	*78*	74	*98*	119	108	137	160	*185*	*193*	175	213	
6d. Colwall	126	31	52	*78*	*90*	*95*	*120*	*147*	155	154	192	199	201	...	
10c. Ashorne	123	45	*54*	77	77	102	112	144	144	*155*	*185*	197	189	...	
11a. Tenbury	119	32	47	73	80	95	126	114	144	155	185	198	179	...	
14a/b. Oxford	115	15	54	67	73	101	107	107	138	153	177	*193*	191	...	
15c. Stratford-on-Avon	124	49	60	85	80	104	122	*108*	152	157	187	189	190	233	
16e. S. Birmingh'm	121	21	51	84	72	*100*	115	117	161	161	182	*196*	196	...	
17a. Edgmond	125	55	*54*	*78*	*83*	106	120	119	149	152	197	*196*	*195*	...	
18*. Oswestry	121	*31*	*54*	73	81	105	119	125	147	158	176	183	197	...	
19b. Granborough	118	6	*54*	70	74	91	122	111	155	154	*185*	*193*	196	...	
19d. Weston Turville	119	*10*	*54*	87	73	99	120	117	146	157	185	*190*	185	...	
20a. Farnborough	118	9	53	61	80	108	117	110	143	153	193	203	188	...	
21b. Erdington	127	28	67	*72*	84	104	122	124	159	171	196	191	201	...	
21d. Hampton-on-the-Hill	116	31	60	65	74	96	105	112	154	149	180	*190*	181	...	
21h. Leamington	119	9	54	72	78	98	120	112	144	152	197	*193*	198	...	
24a. Bletchley	126	43	*54*	94	*83*	104	137	118	152	155	185	188	197	...	
24b. Northampton	119	40	44	*93*	72	93	122	115	152	151	172	*190*	186	...	
26b. Sutton Coldfield.	127	43	55	92	*83*	109	124	126	155	167	*185*	190	195	224	
28a. Little Harrowden	118	52	54	62	70	91	110	105	147	149	197	*190*	189	...	
30a. Mayfield	121	37	46	62	82	101	122	123	153	158	186	188	*193*	...	
34a. Kegworth	121	19	50	*78*	86	103	123	130	152	160	173	188	196	...	
35a. Somershal Herbert	129	7	60	94	94	97	126	149	163	164	192	193	204	...	
35b. Matlock	129	32	52	84	91	110	130	136	156	163	193	193	202	216	
38a. Hodsock	120	36	47	67	77	105	106	112	155	163	196	196	181	...	
39b. Kirkheaton	128	32	51	101	92	*110*	*127*	122	155	*167*	193	193	198	237	
39c. Thurlstone	137	52	51	*100*	96	*120*	149	148	165	171	*195*	196	*198*	...	
39d. Sheffield	131	27	45	91	98	135	123	125	164	168	199	195	*198*	...	
41d. Crosshills	126	41	56	91	91	108	127	116	158	164	171	191	198	206	
44e. Harlington	126	35	57	*78*	97	101	128	119	154	167	*185*	*193*	*193*	...	
45a. Overton	129	44	47	72	93	*103*	146	125	166	161	193	195	*198*	...	
45b. Altofts	128	*40*	*54*	*78*	*95*	*102*	119	126	169	171	172	200	205	...	

* Combination of the three stations 18a, b, c.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926—*continued.*

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's-Bit Scabious.	Ivy.
E (3)															
1*. Barnet	114	38	45	75	71	98	105	113	143	154	170	165	189	...	275
2a. Berkhamsted	117	41	51	56	59	107	121	123	159	*150*	*184*	*169*	*185*	...	...
2b. Tring	110	18	33	60	67	*107*	103	116	133	146	182	168	*185*	...	245
4b. Knebworth	115	35	39	60	79	108	115	112	145	153	*184*	*170*	*185*	...	279
4c. Harpenden	118	28	41	75	73	109	121	117	156	157	*184*	171	*185*	...	276
4h/i. Hitchin	115	21	38	79	69	102	121	117	145	143	178	187	175	...	258
4k. Pirton, Hitchin	118	33	49	84	72	100	123	113	143	146	178	189	183	234	268
4m. Luton	117	*35*	*48*	*76*	*71*	99	120	112	*143*	146	185	191	183	...	...
5a. Turvey	119	37	48	68	71	101	120	114	147	151	188	190	196	227	...
7a. Birch Green	112	12	46	*70*	69	90	*117*	104	*140*	141	179	187	187	216	264
7b. Sawbridgworth	116	31	50	72	75	96	117	111	141	151	*180*	*185*	186	...	272
8a/c. Letchworth	120	27	38	82	61	105	129	124	151	150	191	190	192	...	273
8e/f. Kempston	117	36	46	70	66	95	110	112	144	154	195	*185*	185	207	274
10b. Halstead	116	22	56	65	72	*96*	*116*	120	149	144	*181*	185	188	...	260
10e. Braintree	117	35	55	76	72	96	112	106	155	156	178	*178*	*189*	...	266
10f. Gt. Totham	115	37	53	67	71	*96*	*112*	106	152	144	184	171	190	...	251
11d/e. Cambridge	117	23	50	64	70	109	116	115	150	146	187	*187*	191	...	261
13a. Lexden	116	24	51	78	79	93	103	...	146	146	179	189	189	...	262
14a. Ballingdon	115	10	50	69	75	98	119	119	141	145	190	*185*	184	...	274
17c. Boxford, Colchester	114	8	55	67	76	99	109	114	140	144	182	*185*	*191*	...	285
22b. Langford	125	43	71	71	94	103	121	118	134	154	188	193	213	238	280
22d. Grimston, Lynn	123	33	75	89	73	*102*	107	134	150	143	*185*	198	185	...	267
23c. Framlingham	121	37	*51*	*72*	79	114	116	118	152	149	*186*	*185*	*191*	...	...
24a. Norwich	118	*29*	*51*	70	78	94	104	104	151	154	*187*	*185*	214	...	273
24b. Postwick	119	27	50	78	81	104	108	*108*	155	153	187	184	187	...	266
25d. Hunstanton	123	*29*	64	*72*	93	*108*	121	120	153	162	194	*185*	181	...	248
27c. Cromer	126	32	62	91	91	108	115	112	144	161	190	190	213	231	281
F (7)															
9a. Beaumaris	114	42	43	66	67	97	107	116	135	150	170	196	180	214	...
10a. Wrexham	113	25	46	65	76	*101*	110	107	*135*	151	181	186	*179*	...	287
11d. Trefnant	117	25	50	*66*	69	113	116	112	144	145	188	196	186	242	271
11e. Dolben	120	28	*46*	68	71	*100*	127	*112*	153	147	193	*203*	*190*	...	...
13c. Higher Tranmere	119	24	57	*68*	76	98	112	110	166	173	177	*180*	181	...	260
13d. Shotwick	121	28	53	73	87	103	*118*	111	155	155	191	*190*	190	...	268
14a. Barnton	124	48	46	71	96	115	128	112	150	174	*180*	180	*186*	...	279
14b. Altrincham	133	43	58	93	106	108	121	121	150	161	212	*206*	215	...	275
16b. Bramhall	127	38	60	*85*	100	112	135	117	152	160	183	183	202	...	...
16c. Cheadle Hulme	126	30	48	*87*	92	109	120	122	*154*	163	*188*	*194*	*207*	...	...
18a. Blackpool	137	*60*	71	*96*	*105*	119	138	129	161	*170*	*194*	201	206	...	...
19a. Stockport	133	59	46	96	86	114	139	126	156	167	193	205	212	221	280
21a. Leyland	128	33	58	72	92	107	122	124	158	161	*198*	204	*204*	230	296
22a. Urswick	125	34	59	71	94	107	121	134	156	157	197	190	183	233	255
25b. Ambleside	122	12	43	74	69	112	123	131	159	159	196	194	197	212	270
25c. Windermere	136	*41*	*70*	95	96	114	134	136	165	164	209	*202*	*206*	...	293
28b. Johnby Hall	141	*43*	*71*	102	97	*130*	160	146	*159*	160	*204*	217	*200*	...	...
28c. Mungrisdale	130	32	56	77	91	118	*140*	137	*162*	162	*200*	190	*196*	...	...

* Combination of the three stations 1b, c, d.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926—*continued.*

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's-bit Scabious.	Ivy.
G (9)															
18a. Farragh	122	51	*56*	71	79	*98*	101	121	146	*160*	*193*	190	*200*	...	
32b. Levally	126	40	61	72	84	102	134	121	153	161	193	*195*	201	219	
35c. Warrenpoint	123	24	51	71	72	95	125	120	149	164	197	*198*	204	...	
35d. Rostrevor	122	14	69	98	71	116	117	116	*143*	*154*	*187*	*188*	*194*	...	
47a. Sixtowns	125	20	66	71	80	*109*	120	129	157	155	201	*196*	*202*	201	
48b. Altnafoyle*	130	*40*	62	*77*	84	*106*	119	117	*163*	164	203	*205*	*215*	...	
50a. Hillsborough	134	*60*	65	89	92	*108*	127	131	157	161	195	*204*	218	221	
50c. Belfast	123	65	51	72	*89*	*97*	118	119	163	161	181	*180*	181	...	
50d. Muckamore	129	61	*66*	80	104	*99*	107	120	150	168	192	*197*	*205*	192	
50f. Woodbourne*	137	*66*	72	100	106	112	142	144	*157*	165	191	*194*	*201*	221	
51a. Magherafelt	129	45	66	84	87	*109*	135	140	149	160	191	*190*	193	...	
54a. Hazelbank	127	56	45	79	79	*100*	125	142	155	169	*195*	193	190	216	
54b. Larne	124	59	59	74	*82*	104	111	116	152	158	184	*190*	202	...	
H (6)															
oc. Ramsey, I. of Man†	123	*47*	59	76	86	*104*	118	*118*	*146*	157	*180*	192	*193*	...	
1a. Drummore	132	47	63	96	97	116	128	130	151	161	186	211	196	225	
33a. Ledaig	126	27	*60*	97	79	*110*	125	123	155	156	*187*	*200*	*195*	...	
33b. Kinlochleven	131	*40*	72	91	*90*	*115*	*129*	*129*	166	167	*189*	188	*198*	...	
I (2)															
9a. Ashby	122	52	48	83	84	104	120	115	146	140	*177*	192	185	...	
11c. Weelsby	128	*45*	66	93	‡86	*109*	§127	117	149	163	180	‖109	206	...	
11d. Cleethorpes	121	45	53	73	73	*100*	124	120	168	150	180	183	185	...	
12a. Holderness	128	51	59	85	91	*108*	122	119	152	161	198	*196*	197	...	
13a. Osgodby	128	46	50	*83*	96	113	128	122	148	167	191	*197*	197	...	
20a. Louth	129	38	*48*	*70*	73	101	140	129	164	161	206	210	*214*	234	
21a. Hull	133	39	60	99	108	125	137	140	155	161	180	190	197	...	
23a. Thirsk	122	38	55	82	76	105	128	119	*148*	158	*177*	*187*	*190*	...	
24b. Darlington	125	42	49	73	87	105	129	119	155	162	185	198	197	211	
25.** Corbridge	129	43	51	80	89	105	142	132	164	167	181	201	*192*	195	
25d. Allendale	137	*45*	55	87	99	*115*	153	143	*171*	171	*198*	*205*	*199*	...	
26a. Catcleugh	148	*65*	73	*104*	114	*135*	*160*	156	*182*	180	203	196	*204*	...	
33a. Lanchester	128	38	51	73	102	105	153	137	159	162	*186*	184	*187*	211	
33b. Chopwell	129	30	46	76	91	108	146	130	163	167	201	194	192	201	
36a. S'ton Delaval	131	46	47	85	89	*113*	*137*	127	*163*	173	192	195	*199*	238	
36b. Cockle Park	136	46	53	*92*	95	135	135	136	166	158	197	*200*	214	...	
38a. Falloden	129	36	65	98	93	*105*	120	125	*161*	157	*195*	*192*	*199*	...	
38c. Lemmington	135	55	56	89	93	114	141	135	163	167	203	201	207	225	
39a. Berwick	136	51	55	99	98	122	143	127	173	164	201	196	204	...	
J (1)															
2a. Broughton	143	66	74	95	109	*138*	159	145	166	159	201	196	*205*	210	
4a. Selkirk	131	*52*	59	73	94	*130*	142	129	154	164	192	192	*198*	199	
6a. Gattonside	132	48	47	*86*	104	126	*141*	132	*157*	153	*194*	196	*198*	...	
6b. Jedburgh	135	44	*55*	88	73	120	153	134	171	168	208	199	210	...	
10a. W. Foulden	130	50	54	88	78	*112*	121	122	166	171	202	191	*201*	223	
13a. Stirling	128	34	*47*	84	*93*	*122*	124	131	*155*	158	*193*	*194*	*198*	...	
13c. Gargunnock	131	59	*52*	*78*	86	114	146	131	*157*	*161*	*196*	*197*	*200*	...	
21a. Dundee	131	47	50	86	*88*	*120*	129	128	158	165	*202*	193	203	...	

* Received too late for inclusion in means. † Not included in the means of District H. ‡ At Croxby 8m. S.W. § at Grainsby 8m. S. ‖ at Brocklesby 11m. W. ¶ at Ravendale 7m. S.W. ** Combination of the three stations 25a, c, e.

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TABLE III.—Date (Day of Year) of First Flowering of Plants, 1926—*continued.*

Station.	Mean Value excluding Scabious and Ivy.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Devil's Bit Scabious.	Ivy.
a. Cabrach	138	59	67	93	106	116	137	144	161	169	195	198	*208*	205	274
b. Aberlour	139	*50*	66	73	101	136	157	146	169	160	197	199	*208*	...	...
a. Dunlugas	138	51	56	85	110	135	*143*	144	152	170	204	197	*212*	219	291
b. Forglen	140	57	66	96	99	137	132	144	156	171	204	201	*213*	224	289
c. Huntly	140	*60*	67	92	110	*140*	147	*142*	*152*	157	*202*	*197*	*210*	...	...
a. Cullen	131	*48*	46	78	106	*128*	129	139	*145*	159	*196*	*191*	*204*	...	...
K (o).															
b/c. Muir of Ord	135	54	80	71	96	*131*	138	142	157	158	*193*	196	*206*	...	...
d. Kiltarlity	139	55	89	90	99	*130*	141	*145*	*157*	*160*	*194*	*198*	*208*	...	...
b. Kirkhill	131	57	73	88	96	120	128	138	*148*	152	185	*190*	201	...	303
otal records used	215	241	227	219	260	207	258	286	210	248	169	122	152	82	171

(*Continued from page* 254.)

Migrants (Fig. 6 and Tables IX. to XIII.).—To lessen the chances of error due to the incomplete records of rarer species the main Table XI. has been reduced to 20 instead of the 28 events used since the table was introduced in 1914. As those eliminated and placed in Table XII. are pretty equally scattered among those left in Table XI., it is not likely that the mean value of this series will be materially affected. It will certainly be more reliable. This

(*Continued on page* 271.)

TABLE IV.—Additional Flower Records, etc.

District.	Winter Aconite (*E. hiemalis*).	Snowdrop (*G. nivalis*).	Yellow Crocus (*C. aureus*).	Lesser Celandine (*R. ficaria*).	Mean.	Average, 7 Years, 1920-26.	Difference from Average.	Frog Spawn First Seen.
Channel Isles	[18]	[12]	(23)	22	19	...	...	...
A (8) England S.W.	21	17	30	37	26	22	+4	41
B (10) Ireland S.	11	17	32	41	25	*20	+5	50
C (5) England S.E.	21	24	34	42	30	26	+4	57
D (4) Midlands	21	26	41	53	35	31	+4	61
E (3) England E.	19	22	35	49	31	30	+1	71
F (7) England N.W.	20	25	44	52	35	33	+2	61
G (9) Ireland N.	13	20	37	46	29	27	+2	59
H (6) Scotland W.	(21)	19	(37)	[41]	29	*32	−3	77
I (2) England N.E.	30	30	49	62	43	37	+6	68
J (1) Scotland E.	27	32	51	68	45	47	−2	75
K (0) Scotland N.	20	36	58	68	48	*47	+1	62
Records Used	157	231	216	229	...	...	...	71
Mean of All	21.2	24.4	40.7	50.8	34.2	32.0	+2.2	62.0
Month and Day	J.21	J.24	F.10	F.20	F.3	F.1	...	M.3
Average, 14 yrs., 1913-26	18.0	22.2	37.5	48.2	31.5	...	...	...
Month and Day	J.18	J.22	F.6	F.17	J.31	...	...	...

* Full 7-year period not available.

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TABLE V.—Mean Dates (Day of Year) for the Flowering of Fourteen Plants in 1926 and Difference from the Average of the 35 Years, 1891-1925.

Plants.	Channel Isles 1926.	A (8) England, S.W. 1926.	A (8) Average 35 years.	A (8) Difference from Average.	B (10) Ireland, S. 1926.	B (10) Average 35 years.	B (10) Difference from Average.	C (5) England, S.E. 1926.	C (5) Average 35 years.	C (5) Difference from Average.	D (4) England, Mid. 1926.	D (4) Average 35 years.	D (4) Difference from Average.	E (3) England, E. 1926.	E (3) Average 35 years.	E (3) Difference from Average.	F (7) Eng., N.W. 1926.	F (7) Average 35 years.	F (7) Difference from Average.
1. Hazel (*Corylus avellana*)	[31]	29	38	− 9	37	33	+ 4	29	32	− 3	31	41	− 10	29	35	− 6	34	43	− 9
2. Coltsfoot (*Tussilago farfara*)	...	50	55	− 5	53	58	− 5	50	58	− 8	54	63	− 9	51	61	− 10	53	62	− 9
3. Wood Anemone (*Anemone nemorosa*)	[66]	70	84	− 14	60	77	− 17	70	82	− 12	78	89	− 11	72	88	− 16	78	90	− 12
4. Blackthorn (*Prunus spinosa*)	81	74	89	− 15	78	82	− 4	77	94	− 17	83	99	− 16	75	96	− 21	86	102	− 16
5. Garlic Hedge-Mustard (*Sisymbrium alliaria*)	[106]	100	107	− 7	101	112	− 11	99	110	− 11	103	113	− 10	102	111	− 9	109	122	− 13
6. Horse-Chestnut (*Æsculus hippocastanum*)	120	116	122	− 6	115	123	− 8	116	126	− 10	120	130	− 10	116	126	− 10	126	132	− 6
7. Hawthorn (*Crataegus oxyacantha*)	108	115	130	− 15	123	131	− 8	115	130	− 15	120	133	− 13	116	131	− 15	123	138	− 15
8. White Ox-Eye (*Chrysanthemum leucanthemum*)	...	144	145	− 1	147	144	+ 3	139	141	− 2	152	149	+ 3	147	145	+ 2	154	154	± 0
9. Dog Rose (*Rosa canina*)	155	153	155	− 2	160	158	+ 2	154	155	− 1	159	159	± 0	150	155	− 5	159	162	− 3
10. Black Knapweed (*Centaurea nigra*)	[189]	176	172	+ 4	192	184	+ 8	175	171	+ 4	185	177	+ 8	184	177	+ 7	191	189	+ 2
11. Harebell (*Campanula rotundifolia*)	[191]	196	193	+ 3	[190]	185	[+ 5]	193	186	+ 7	193	191	+ 2	185	189	− 4	195	188	+ 7
12. Greater Bindweed (*Convolvulus sepium*)	(177)	188	186	+ 2	201	192	+ 9	192	187	+ 5	193	191	+ 2	191	190	+ 1	195	196	− 1
13. Devil's-Bit Scabious (*Scabiosa succisa*)	...	218	...	...	220	...	...	223	...	...	222	...	...	225	...	...	225	...	...
14. Ivy (*Hedera helix*)	(258)	265	264	+ 1	264	263	+ 1	268	269	− 1	268	268	± 0	268	266	+ 2	276	277	− 1
Mean of Plants 1-7	...	79	89	−10	81	88	− 7	79	90	−11	84	95	−11	80	93	- 13	87	98	−11
Mean of Plants 8-12	...	171	170	+ 1	178	173	+ 5	171	168	+ 3	176	173	+ 3	171	171	± 0	179	178	+ 1
Mean of the 13 Plants (excluding Scabious)	...	129	134	− 5	132	134	− 2	129	135	− 6	134	139	− 5	130	136	- 6	137	143	− 6
Mean of the 14 Plants (including Scabious)	...	135	...	...	139	...	...	136	...	...	140	...	...	137	...	...	143	...	...

	G (9) Ireland, N.			H (6) Scotland, W.			I (2) England, N.E.			J (1) Scotland, E.			K (0) Scotland, N.			England and Wales.*			British Isles.†		
1. Hazel	43	48	− 5	44	49	− 5	45	46	− 1	52	55	− 3	57	50	+ 7	33	39	− 6	39	44	− 5
2. Coltsfoot	59	67	− 8	69	67	+ 2	55	64	− 9	61	73	− 12	81	76	+ 5	52	60	− 8	58	64	− 6
3. Wood Anemone	79	88	− 9	95	97	- 2	87	93	− 6	86	104	− 18	83	107	− 24	76	88	− 12	78	91	− 13
4. Blackthorn	84	100	−16	91	112	−21	92	107	− 15	99	116	−17	97	115	− 18	81	98	− 17	85	101	−16
5. Garlic Hedge-Mustard	104	112	− 8	[116]	127	[−11]	110	121	− 11	126	128	− 2	[120]	128	[− 8]	104	114	− 10	108	119	− 11
6. Horse-Chestnut	120	131	−11	131	142	−11	134	138	− 4	140	145	− 5	136	142	− 6	121	129	− 8	125	133	− 8
7. Hawthorn	126	138	− 12	134	145	−11	129	139	−10	138	148	−10	143	152	− 9	120	133	−13	126	139	−13
8. White Ox-Eye	153	155	− 2	155	160	− 5	160	157	+ 3	161	164	− 3	[157]	167	[− 10]	149	148	+ 1	152	154	− 2
9. Dog Rose	162	165	− 3	161	166	− 5	164	167	− 3	164	169	− 5	158	169	−11	157	159	− 2	159	163	− 4
10. Black Knapweed	192	198	− 6	[186]	199	[−13]	194	192	+ 2	200	198	+ 2	[185]	204	[− 19]	184	180	+ 4	187	190	− 3
11. Harebell	(191)	196	(− 5)	(199)	194	(+ 5)	196	191	+ 5	196	195	+ 1	(193)	197	(- 4)	193	189	+ 4	193	192	+ 1
12. Greater Bindweed	198	203	− 5	[196]	198	[− 2]	198	198	± 0	(211)	207	(+ 4)	[201]	202	[− 1]	193	191	+ 2	197	198	− 1
13. Devil's-Bit Scabious	209	...	...	[225]	...	...	219	...	...	214	...	...	*216*	...	...	222	...	...	220	...	...
14. Ivy	275	277	− 2	[268]	277	[− 9]	277	280	− 3	285	290	− 5	(298)	291	(+ 7)	270	270	± 0	274	276	− 2
Mean of Plants 1-7	88	98	−10	97	106	− 9	93	101	− 8	100	110	−10	102	110	− 8	84	94	−10	88	99	−11
Mean of Plants 8-12	179	183	− 4	179	183	− 4	182	181	+ 1	188	187	+ 1	179	188	− 9	175	173	+ 2	178	179	− 1
Mean of the 13 Plants	137	144	− 7	142	149	− 7	142	146	− 4	148	153	− 5	147	154	− 7	133	138	− 5	137	143½	−6½
Mean of the 14 Plants	141	...	...	148	...	...	147	...	...	153	...	...	152	...	...	140	...	...	143	...	...

* Average of Districts A, C, D, E, F, I. † The mean of the 13 plants for the British Isles is given to the nearest half-day.

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TABLE VI.—Mean Dates of Flowering, with their Variations from the 35 Years' Average (1891-1925), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made. Also, Total Number of Stations in all Eleven Districts.

Year.	No. of Stations.	A (8), Eng. SW.		C (5), Eng. SE.		D (4), Eng. Mid.		E (3), Eng. E.		F (7), Eng. N.W		H (6), Scot. W.		I (2), Eng. NE.		J (1), Scot. E.		Mean Difference from Average for the 8 Districts.
		Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	
†1891	105	144	+10	144	+ 9	150	+11	147	+11	150	+ 7	162	+13	157	+11	161	+ 8	+10.0
†1917	114	142	+ 8	141	+ 6	149	+10	145	+ 9	148	+ 5	153	+ 4	152	+ 6	160	+ 7	+ 6.9
‡1893	117	118	−16	122	−13	125	−14	123	−13	128	−15	136	−13	137	− 9	146	− 7	−12.5
‡1921	205	125	− 9	128	−15	127	−12	125	−11	133	−10	149	0	130	−16	145	− 8	−10.1
*1924	365	139	+ 5	138	+ 3	144	+ 5	141	+ 5	149	+ 6	152	+ 3	148	+ 2	163	+10	+ 4.9
1925	362	136	+ 2	134	− 1	138	− 1	135	− 1	143	0	143	− 6	144	− 2	156	+ 3	− 0.7
1926	373	129	− 5	129	− 6	134	− 5	130	− 6	137	− 6	142	− 7	142	− 4	148	− 5	− 5.5
Avge.	...	134	...	135	...	139	...	136	...	143	...	149	...	146	...	153	...	142
1891–1925		My 14		My 15		My 19		My 16		My 23		My 29		My 26		Jn. 2		My 22

* Leap year. † Two latest years. ‡ Two earliest years.

(*Continued from page* 269.)

mean value for 1926 falls 2½ days earlier than the 14 years average. Taking the three sections, 1 to 5 to April 20, 6 to 12, April 22-29, and 13 to 20, May 2 to 17, we find a decreasing earliness of 4, 2½ and 1 days. The decided break after the middle of April, with only the whitethroat between the house martin on the 23rd and the lesser whitethroat on the 30th, once more emphasizes the access of cold after the hot Easter. This is further shown by the crowding of the bird isophenes 109, 112, 115, 118, SW from the Wash and 112-118 in NW England. The migrants almost stood still. In the absence at present of isophenes for the earlier years and the resultant average isophene map an isakair chart is not available.

The Additional Bird Records (Table XIII.) serve to emphasize the spring earliness of 1926. The table does not, however, bring out one of the most striking facts as to the return migration of house martin and swallow. But this is shown by our observer's notes (p. 275) and many of the original records of this Table and of Table XI. The remarkable lateness there shown in certain stations is marked by unusually early departures from other localities. It would almost suggest that in the former set the birds returned again, repenting their premature departure.

Migrant Isophenes (Fig. 6).—In 1925 isophene 109 shows only along the coast of Sussex and to the Isle of Wight, with two small loops inland. In 1926 isophene 106 appears in Cambridgeshire and a band earlier than 109 from the Wash surrounds it and reaches E Hants and passes E along the Thames. Its southern

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TABLE V.—Mean Dates (Day of Year) for the Flowering of Fourteen Plants in 1926 and Difference from the Average of the 35 Years, 1891-1925.

Plants.	Channel Isles 1926.	A (8) England, S.W. 1926.	Average 35 years.	Difference from Average.	B (10) Ireland, S. 1926.	Average 35 years.	Difference from Average.	C (5) England, S.E. 1926.	Average 35 years.	Difference from Average.	D (4) England, Mid. 1926.	Average 35 years.	Difference from Average.	E (3) England, E. 1926.	Average 35 years.	Difference from Average.	F (7) Eng., N.W. 1926.	Average 35 years.	Difference from Average.
1. Hazel (*Corylus avellana*)	[31]	29	38	− 9	37	33	+ 4	29	32	− 3	31	41	− 10	29	35	− 6	34	43	− 9
2. Coltsfoot (*Tussilago farfara*)	...	50	55	− 5	53	58	− 5	50	58	− 8	54	63	− 9	51	61	− 10	53	62	− 9
3. Wood Anemone (*Anemone nemorosa*)	[66]	70	84	− 14	60	77	− 17	70	82	− 12	78	89	− 11	72	88	− 16	78	90	− 12
4. Blackthorn (*Prunus spinosa*)	81	74	89	− 15	78	82	− 4	77	94	− 17	83	99	− 16	75	96	− 21	86	102	− 16
5. Garlic Hedge-Mustard (*Sisymbrium alliaria*)	[106]	100	107	− 7	101	112	− 11	99	110	− 11	103	113	− 10	102	111	− 9	109	122	− 13
6. Horse-Chestnut (*Æsculus hippocastanum*)	120	116	122	− 6	115	123	− 8	116	126	− 10	120	130	− 10	116	126	− 10	126	132	− 6
7. Hawthorn (*Crataegus oxyacantha*)	108	115	130	− 15	123	131	− 8	115	130	− 15	120	133	− 13	116	131	− 15	123	138	− 15
8. White Ox-Eye (*Chrysanthemum leucanthemum*)	...	144	145	− 1	147	144	+ 3	139	141	− 2	152	149	+ 3	147	145	+ 2	154	154	± 0
9. Dog Rose (*Rosa canina*)	155	153	155	− 2	160	158	+ 2	154	155	− 1	159	159	± 0	150	155	− 5	159	162	− 3
10. Black Knapweed (*Centaurea nigra*)	[189]	176	172	+ 4	192	184	+ 8	175	171	+ 4	185	177	+ 8	184	177	+ 7	191	189	+ 2
11. Harebell (*Campanula rotundifolia*)	[191]	196	193	+ 3	[190]	185	[+ 5]	193	186	+ 7	193	191	+ 2	185	189	− 4	195	188	+ 7
12. Greater Bindweed (*Convolvulus sepium*)	(177)	188	186	+ 2	201	192	+ 9	192	187	+ 5	193	191	+ 2	191	190	+ 1	195	196	− 1
13. Devil's-Bit Scabious (*Scabiosa succisa*)	...	218	...	...	220	...	...	223	...	...	222	...	...	225	...	...	225	...	...
14. Ivy (*Hedera helix*)	(258)	265	264	+ 1	264	263	+ 1	268	269	− 1	268	268	± 0	268	266	+ 2	276	277	− 1
Mean of Plants 1-7	...	79	89	− 10	81	88	− 7	79	90	− 11	84	95	− 11	80	93	− 13	87	98	− 11
Mean of Plants 8-12	...	171	170	+ 1	178	173	+ 5	171	168	+ 3	176	173	+ 3	171	171	± 0	179	178	+ 1
Mean of the 13 Plants (excluding Scabious)	...	129	134	− 5	132	134	− 2	129	135	− 6	134	139	− 5	130	136	− 6	137	143	− 6
Mean of the 14 Plants (including Scabious)	...	135	...	...	139	...	...	136	...	...	140	...	...	137	...	...	143	...	...

	G (9) Ireland, N.			H (6) Scotland, W.			I (2) England, N.E.			J (1) Scotland, E.			K (0) Scotland, N.			England and Wales.*			British Isles.†		
1. Hazel	43	48	− 5	44	49	− 5	45	46	− 1	52	55	− 3	57	50	+ 7	33	39	− 6	39	44	− 5
2. Coltsfoot	59	67	− 8	69	67	+ 2	55	64	− 9	61	73	− 12	81	76	+ 5	52	60	− 8	58	64	− 6
3. Wood Anemone	79	88	− 9	65	97	− 2	87	93	− 6	86	104	− 18	83	107	− 24	76	88	− 12	78	91	− 13
4. Blackthorn	84	100	− 16	91	112	− 21	92	107	− 15	99	116	− 17	97	115	− 18	81	98	− 17	85	101	− 16
5. Garlic Hedge-Mustard	104	112	− 8	[116]	127	[− 11]	110	121	− 11	126	128	− 2	[120]	128	[− 8]	104	114	− 10	108	119	− 11
6. Horse-Chestnut	120	131	− 11	131	142	− 11	134	138	− 4	140	145	− 5	136	142	− 6	121	129	− 8	125	133	− 8
7. Hawthorn	126	138	− 12	134	145	− 11	129	139	− 10	138	148	− 10	143	152	− 9	120	133	− 13	126	139	− 13
8. White Ox-Eye	153	155	− 2	155	160	− 5	160	157	+ 3	161	164	− 3	[157]	167	[− 10]	149	148	+ 1	152	154	− 2
9. Dog Rose	162	165	− 3	161	166	− 5	164	167	− 3	164	169	− 5	158	169	− 11	157	159	− 2	159	163	− 4
10. Black Knapweed	192	198	− 6	[186]	199	[− 13]	194	192	+ 2	200	198	+ 2	[185]	204	[− 19]	184	180	+ 4	187	190	− 3
11. Harebell	(191)	196	(− 5)	(199)	194	(+ 5)	196	191	+ 5	196	195	+ 1	(193)	197	(− 4)	193	189	+ 4	193	192	+ 1
12. Greater Bindweed	198	203	− 5	[196]	198	[− 2]	198	198	± 0	(211)	207	(+ 4)	[201]	202	[− 1]	193	191	+ 2	197	198	− 1
13. Devil's-Bit Scabious	209	...	...	[225]	...	...	219	...	...	214	...	...	*216*	...	...	222	...	...	220	...	...
14. Ivy	275	277	− 2	[268]	277	[− 9]	277	280	− 3	285	290	− 5	(298)	291	(+ 7)	270	270	± 0	274	276	− 2
Mean of Plants 1-7	88	98	− 10	97	106	− 9	93	101	− 8	100	110	− 10	102	110	− 8	84	94	− 10	88	99	− 11
Mean of Plants 8-12	179	183	− 4	179	183	− 4	182	181	+ 1	188	187	+ 1	179	188	− 9	175	173	+ 2	178	179	− 1
Mean of the 13 Plants	137	144	− 7	142	149	− 7	142	146	− 4	148	153	− 5	147	154	− 7	133	138	− 5	137	143	− 6
Mean of the 14 Plants	143	...	...	148	...	...	147	...	...	154	...	...	153	...	...	140	...	...	144	...	...

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		Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	Day of Year.	Diff. from Average.	
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1925	362	136	+ 2	134	− 1	138	− 1	135	− 1	143	0	143	− 6	144	− 2	156	+ 3	− 0.7
1926	373	129	− 5	129	− 6	134	− 5	130	− 6	137	− 6	142	− 7	142	− 4	148	− 5	− 5.5
Avge.	...	134	...	135	...	139	...	136	...	143	...	149	...	146	...	153	...	142
1891–1925		My 14		My 15		My 19		My 16		My 23		My 29		My 26		Jn. 2		My 22

* Leap year. † Two latest years. ‡ Two earliest years.

(*Continued from page* 269.)

mean value for 1926 falls 2½ days earlier than the 14 years average. Taking the three sections, 1 to 5 to April 20, 6 to 12, April 22-29, and 13 to 20, May 2 to 17, we find a decreasing earliness of 4, 2½ and 1 days. The decided break after the middle of April, with only the whitethroat between the house martin on the 23rd and the lesser whitethroat on the 30th, once more emphasizes the access of cold after the hot Easter. This is further shown by the crowding of the bird isophenes 109, 112, 115, 118, SW from the Wash and 112-118 in NW England. The migrants almost stood still. In the absence at present of isophenes for the earlier years and the resultant average isophene map an isakair chart is not available.

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bounding isophene (109) then works round near the coast to Weymouth. The Hampshire loop nearly meets the same isophene from the Wash; 109 reappears over N Somersetshire and W Gloucestershire; 112 from the Wash, circles round the Midlands and up to the Lake District, thence across the I. of Man to Belfast Lough. From there it works along the E and S Irish coasts. The latest isophene is 121, compared with 127 indicated over the northern Highlands in 1925.

The HEVINGHAM RECORD (Table XIV., by Major H. S. Marsham) repeats for 1926 Table IX. of 1925. The records kept by the Marsham family, it may be recalled, go back to 1736 and are a unique series.

SUMMARY OF OBSERVERS' NOTES.

WEATHER. I36a, speaks of cold spring and fine summer. E14b, Essex dry in early Jan. Cold lasted to mid-Jan. Feb. 28, hottest Feb. day in 50 years. B14b, spring and summer unequalled. I24b, gives a good, brief summary of weather and its effect on plants, birds and insects. Many records of mischievous mid-May frosts and preceding cold; also absence of sunshine; apple failure specially noted. The killing late October frosts are spoken of in all districts. F25c, records also heavy snow (Oct. 24), breaking off tree limbs. J40b, vegetation knocked down by frost, hail and sleet, Oct. 20.

PLANTS. A5c, points out there being two forms of *Centaurea nigra*, the earlier flowering *obscura* and later *nemoralis*, thus resembling *Cratægus monogyna* and *oxyacanthoides*. The drastic effects of the sharp October frosts on autumn tints and leaf fall receive widespread notice; foliage often as if burnt, the leaves dropping prematurely but in some cases hanging on as after late spring frosts. The oak was often an exception. D14b, by grouping his flower records in ten-day periods from Jan. to mid-July, found a gradual reduction in earliness from 24 to 2 days. 16e, came upon undoubted *Scabiosa succisa* on July 1. 24b, flowers at end of March six weeks earlier than in 1925. Station H33b, gets no sun from Nov. to Feb., thanks to mountains with snowline at 1,000ft. J36a, general earliness, scabious and ivy give earliest record.

PROFUSE FLOWERING is little mentioned, save of sloe and may, also field poppies in N.E. But the autumn herbaceous plants made considerable amends.

SECOND FLOWERING also was limited, except of fruit trees affected by May frosts. In some parts fruit followed, as ripe plums at Christmas in Street, A22c. As a rule such hopes were blighted by the October frosts.

FRUITING. General apple failure, the April-May conditions subjecting premature blossom to severe frosts. Plum and pear fared better, and most berries, except early strawberries and gooseberries. Wild fruits, except crabs, were plentiful, especially blackberry, hazel, haws and holly. I38c, notes no heather honey for bees. Districts suffering from the late Aug. and Sept. drought note scarcity of mushrooms and most other fungi. A25b, records mushrooms in the open on Feb. 28. C15d, notes that rhubarb was almost unobtainable.

CROPS. Though in parts meadows were "not so green in May as in Feb." (A17) reports on hay crops were generally good; so, too, with

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TABLE VII.—Observations of Trees and Shrubs taken at St. Michael's, Tenbury, Worcestershire, 1926, by Frederick Lowe.

Date given by day of year. For equivalent monthly dates see explanation on page 241.

Common Name.	Latin Name.	First Flower.	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
1. Alder	*Alnus glutinosa*	71	114	126	269	304	309	297
2. Apple (Wild)	*Pyrus malus*	97	92	105	257	291	304	288
3. ,, (Cultivated)	*Pyrus malus sativus*	97	91	105	235	290	304	242
4. Ash	*Fraxinus excelsior.*	87	131	146	258	291	302	276
5. ,, (Mountain)	*Pyrus aucuparia*	121	84	98	241	285	307	220
6. Acacia	*Robinia pseud-acacia*	165	115	149	257	293	307	276
7. Almond	*Amygdalus communis*	65	88	109	266	303	315	300
8. Berberis (Dar)	*Berberis Darwinii*	...	...	...	...	...	...	197
9. ,, (Aqui)	*Berberis aquifolium*	...	...	...	...	...	...	219
10. Barberry	*Berberis vulgaris*	115	69	107	252	298	315	266
11. Blackthorn	*Prunus spinosa*	80	94	108	258	281	303	255
12. Birch	*Betula alba*	104	90	98	234	300	313	242
13. Beech	*Fagus sylvatica*	118	104	112	241	301	313	266
15. Box	*Buxus sempervirens*	54	66	107	(Cas	ting	103)	...
16. Currant (Black)	*Ribes nigrum*	93	69	94	227	285	311	178
17. ,, (Red)	*Ribes rubrum*	94	84	96	234	272	298	178
18. Chestnut (Horse)	*Æsculus hippocastanum*	126	88	104	256	281	303	278
19. ,, (Spanish)	*Castanea vesca*	195	114	126	268	304	317	290
20. Cherry (Wild)	*Prunus avium*	89	87	100	246	286	298	202
21. ,, (Bird)	*Prunus padus*	115	92	104	241	286	297	190
22. ,, (Cultivated)	*Cerasus vulgaris*	92	96	109	238	289	302	170
23. Cypress (Common)	*Cupressus sempervirens*	129	125	147	...	...	...	272
24. Cedar	*Cedrus libani*	261	108	134	(Cas	ting	177)	292
25. Dogwood	*Cornus sanguinea*	159	93	105	219	290	313	287
27. Elm (Common)	*Ulmus campestris*	51	129	148	270	307	321	126
28. ,, (Cornish)	*Ulmus stricta*	50	76	104	261	305	319	120
29. ,, (Cork)	*Ulmus suberosa*	53	119	124	258	291	311	120
30. ,, (Wych)	*Ulmus montana*	55	95	119	234	288	306	119
31. Elder	*Sambucus nigra*	143	15	90	232	273	302	245
32. Fir (Spruce)	*Abies excelsa*	107	115	134	(Cas	ting	224)	261
33. ,, (Scots)	*Pinus sylvestris*	125	130	155	(Cas	ting	222)	272
34. Gooseberry	*Ribes grossularia*	88	57	94	234	269	292	192
35. Gorse	*Ulex europæus*	61	91	119	...	...	...	208
36. ,, (Dwarf)	*Ulex nanus*	220	121	146	...	...	...	317
37. Hazel	*Corylus avellana*	32	84	104	231	288	306	248
38. Hawthorn	*Cratægus oxyacantha*	114	53	90	241	281	309	245
39. Holly	*Ilex aquifolium*	116	130	144	(Cas	ting	146)	289
40. Honeysuckle	*Lonicera caprifolium*	139	6	84	227	270	306	215
41. ,, (Wild)	*Lonicera periclymenum*	162	7	91	241	293	317	221
42. Ivy	*Hedera helix*	260	97	120	(Cas	ting	43)	56
44. Jasmine (Yellow)	*Jasminum nudiflorum*	269	...	...	234	288	302	...
45. ,, (White)	*Jasminum officinale*	188	117	153	...	...	...	...
47. Laburnum	*Cytisus laburnum*	109	78	101	200	299	309	270
49. Laurel (Portugal)	*Cerasus lusitanica*	99	97	129	(Cas	ting	93)	256
52. ,, (Common)	*Cerasus laurocerasus*	95	98	130	(Cas	ting	90)	270
53. Larch	*Pinus larix*	73	73	96	259	302	320	263
54. Lilac	*Syringa vulgaris*	101	55	90	240	296	306	286
55. Lime	*Tilia europæa*	189	94	118	234	277	293	261
56. Lavender	*Lavendula vera*	197	72	121	(Cas	ting	233)	279
57. Maple (Field)	*Acer campestre*	118	98	105	248	281	302	285
58. ,, (Norway)	*Acer platanoides*	92	99	115	246	277	192	277
59. Medlar	*Mespilus germanica*	119	86	99	268	292	307	299
60. Mezereon	*Daphne mezereum*	1	55	107	219	285	297	170
61. Mistletoe	*Viscum album*	...	...	...	...	...	...	...
62. Oak (Acorns on stems)	*Quercus robur*	103	100	118	258	309	324	288
63. ,, (Acorns sessile)	*Quercus sessiliflora*	100	97	115	253	304	321	288

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TABLE VII.—Observations of Trees and Shrubs taken at St. Michael's, Tenbury, Worcestershire, 1926, by Frederick Lowe—*continued.*

Common Name.	Latin Name.	First Flower.	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
64. Poplar (White) .	*Populus alba* . .	84	97	114	248	289	304	104
65. ,, (Grey) .	*Populus canescens* .	90	127	143	258	306	314	101
66. ,, (Black) .	*Populus nigra* . .	74	105	120	246	290	301	92
67. ,, (Lombardy) .	*Populus fastigiata* .	64	91	102	247	304	309	84
68. ,, (Aspen) .	*Populus tremula* . .	60	105	111	249	292	306	105
69. Privet . . .	*Ligustrum vulgare* .	175	79	98	(Cas	ting	236)	295
70. Pear (Common) .	*Pyrus communis* . .	84	92	99	240	282	303	269
71. Plum (Common) .	*Prunus domestica* . .	77	77	100	232	277	292	241
72. ,, (Pershore) .	*Prunus Pershorum* .	...	...	...	233	276	302	237
73. Quince . . .	*Cydonia vulgaris* . .	115	89	100	269	297	306	...
74. Ribes . . .	*Ribes floridum* . .	71	79	97	248	280	303	...
75. Rosemary . .	*Rosmarinus officinalis* .	102	29	105	(Cas	ting	189)	233
76. Raspberry . .	*Rubus idæus* . .	149	60	106	219	277	301	178
77. Rose (Guelder) .	*Viburnum opulus* . .	146	100	107	240	289	305	237
78. ,, (Field) . .	*Rosa arvensis* . .	163	66	95	239	272	308	246
79. ,, (Dog) . .	*Rosa canina* . .	155	93	115	227	282	310	247
80. Service (Wild). .	*Pyrus torminalis* . .	...	...	...	...	...	...	...
81. Snowberry . .	*Symphoricarpus racemosus*	83	79	95	255	302	316	269
82. Syringa . . .	*Philadelphus coronarius*	143	60	90	238	270	298	246
83. Spindle . . .	*Euonymus europæus* .	141	79	96	237	286	302	277
84. Sycamore . .	*Acer pseudo-platanus* .	105	92	104	242	288	302	259
86. Willow (Goat) .	*Salix caprea* . .	65	92	101	240	290	316	144
87. ,, (Common) .	*Salix fragilis and viminalis*	100	73	99	246	289	317	144
88. ,, (White) .	*Salix alba* . . .	101	90	101	259	297	317	155
89. Walnut . . .	*Juglans regia* . .	125	96	135	238	280	299	275
90. Yew . . .	*Taxus baccata* . .	59	100	128	(Cas	ting	175)	235

Seven Selected Trees.

Averages, 1915-24.

Common Name.	First Flower.	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
13. Beech . .	133	113	125	227	209	313	255
18. Chestnut (Horse)	127	99	117	247	280	302	267
27. Elm (Common)	54	124	145	267	310	331	123
37. Hazel . .	30	103	125	236	288	314	246
38. Hawthorn .	126	78	107	239	286	305	239
57. Maple (Field)	133	120	132	249	283	306	269
84. Sycamore .	119	105	121	244	287	303	263
Av. of all 7 (Day of Yr).	103	106	125	244	289	311	238
Ditto, Day of Month...	Ap 13	Ap. 16	My 5	Sp. 1	Oc. 16	N. 7	Au. 26

Difference of 1926 from Average

First Flower	First Leaf.	Full Leaf.	First Tint.	Full Tint.	Leafless.	Fruit Ripe.
−15	− 9	−13	+14	+12	0	+11
− 1	−11	−13	+ 9	+ 1	+ 1	+11
− 3	+ 5	+ 3	+ 3	− 3	−10	+ 3
+ 2	−19	−21	− 5	0	− 8	+ 2
−12	−25	−17	+ 2	− 5	+ 4	+ 5
−15	−22	−27	− 2	− 2	− 4	+17
−14	−13	−17	− 2	+ 1	− 1	+ 7
− 8.3	− 13.4	− 15.0	+ 2.9	+ 0.6	− 2.6	+ 7.9

Mean of the 7.

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TABLE VIII.—Additional Records of Plants on the International List.
(Dates of First Flowering unless otherwise stated.)

British Isles Means.	Christmas Rose (1925/6) (*Helleborus niger*).	Almond (*Amygdalus communis*).	Horse Chestnut Leafing.	Red Currant (*Ribes rubrum*).	Oak (Acorns on Stems) (*Quercus pedunculata*).	Purple Lilac (*Syringa vulgaris*).	Bird Cherry (*Prunus padus*).	Laburnum (*Cytisus laburnum*).	Elder (*Sambucus nigra*).	White Acacia (*Robinia pseud-acacia*).	Madonna Lily (*Lilium candidum*).	Autumn Crocus (*Colchicum autumnale*).	Horse Chestnut Fruit Ripe.	Horse Chestnut Leafless
Total Records Used	3	9	20	16	19	36	11	34	28	6	12	11	7	9
Mean of all . .	—11	62	91	98	109	112	117	121	150	178	186	248	241	306
Month and Day .	Dec. 21	Mar. 3	Apr. 1	Apr. 8	Apr. 19	Apr. 22	Apr. 27	May 1	May 30	Jun. 27	Jul. 5	Sep. 5	Aug. 29	Nov. 2

(*Continued from page* 272.)

grain and roots, though on threshing, grain was disappointing. In some parts potatoes suffered seriously in Oct., and elsewhere were small from the May-June conditions, though other districts gave heavy crops. I9b, reports that the Gainsborough Show records from 1 lb. of seed were high, the prize going to a crop of 338 lbs., a single "eye" producing 13 lbs. The Aug.-Sept. weather was mainly responsible for the falsifying of the end July gloomy vaticinations. I33b, summarized it that "despite the peculiar cool summer, the final results were first-rate for farmers."

General Bird Notes. Naturally many refer to the abnormally early, though sporadic, arrival of the earlier migrants, particularly the cuckoo and true swallows. With the later migrants the reverse was frequent. A36b, records the earliest arrival of sandmartin and swift, but especially of the chiffchaff on March 19. The last gave similar records at Aoa and B27a. Several report abnormal flocking of birds in autumn. A22c, of migrating geese, peewits and pied wagtails. B43b, an extraordinary immigration of tens of thousands of rooks, more fustian coloured than the local birds, at the end of Oct.; but total absence of usual flocks of wood pigeons until the rooks left at the turn of the year. In 1925 the same occurred. C1a, records many thousands of skylarks going west. C3a, vast movements of larks and wood pigeons after the 1925/6 cold spell. C4b, some hundred goldfinches, the largest flock ever seen. Also great mortality of pheasant and partridge chicks, first from scarcity of ants' eggs, later from gapes in July. E4i, pied flycatcher nesting at Welwyn; first authentic Herts record. I38c, rowans cleared by ring ouzels, end Sept. Nov.-Dec. 1925 frosts disastrous for birds; during rounds noted 57 chaffinches, ten robins, uncounted blackbirds, thrushes, sparrows, etc., six titmice (*cf.* I19a, p. 316 in 1925 Report).

Rarer in 1926 were corncrake, cuckoo in some parts, and swallow. *More common*, grasshopper warbler; G35c, specially notes pest of missel thrushes (in contrast to the first Report, apparently extinct from the severe 1891 season) and blackbirds; also more bramblings. I20a, numbers of redwing, fieldfare, hooded crow in Oct. So fieldfare, K25a. Goldfinch, raven and buzzard in Devon. The late stay of the swallow tribe is repeatedly noted.

(*Continued on page* 282.)

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926.

Song-Thrush (*Turdus musicus*) first heard; Swallow (*Hirundo rustica*) first seen; Cuckoo (*Cuculus canorus*) first heard; Nightingale (*Daulias luscinia*) first heard; Flycatcher (*Muscicapa grisola*) first seen; Swallow (*Hirundo rustica*) last seen; Honey-Bee (*Apis mellifica*); Wasp (*Vespa vulgaris*); Small White Butterfly (*Pieris rapæ*); Orange-Tip Butterfly (*Anthocaris cardamines*); Meadow-Brown Butterfly (*Epinephile janira*); Humble Bee (*Bombus lapidarius*) first seen.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
A. Channel Isles:												
Guernsey,												
0a. Les Blanches	1	95	104	...	...	313	...	...	103	...	164	*154*
0b. South Coast	1	...	103	...	137	...	...	...	...	...	...	...
0d. Les Hubits	1	107	103	...	...	301	...	104	96	...	169	...
Jersey,												
0e. Westmount	*24*	114	115	...	121	316	52	...	83	103	144	*144*
A (8)												
1a. Carbis Bay	2	109	114	...	...	294	55	94	97	111	...	...
1b. St. Buryan	1	93	118	...	143	306	56	91	103	124	...	56
4b. Lambourne Hill	2	100	114	...	...	311	72	...	*70*	123	136	*114*
5* Polperro	1	101	118	...	...	311	...	...	80	123	...	...
5d. Bodmin	2	99	105	...	...	...	32	...	...	...	...	...
6a. Duloe	2	*73*	114	...	...	306	30	68	101	*164*	*101*	58
6c. Lopwell	10	119	110	...	136	*255*	80	97	102	102	158	102
8b. Buckfastleigh	4	99	114	...	...	304	35	...	...	126	...	71
9a. Launceston	4	102	103	...	...	...	55	...	99	117	...	...
9b. Hexworthy	...	102	119	...	...	...	37	97	102	124	...	...
9c. Clawton	11	113	115	...	...	...	79	...	115	130	...	...
10b. Torquay	1	103	103	...	...	276	*2*	93	*123*	123	*103*	...
11d. Copplestone	11	98	112	...	131	298	49	93	...	130	...	...
11e. Lydford	5	98	114	...	...	274	...	99	99	...	...	...
13a. Exmouth	1	102	104	...	130	309	38	92	92	...	...	66
13c. Exeter	1	109	117	...	...	285	74	...	*133*	139	...	74
14a. Umberleigh	8	98	95	...	143	264	12	92	100	103	170	95
14b. Bish'p's Tawton	1	94	106	...	...	...	59	12	101	...	...	...
14d. Barnstaple	...	113	...	...	143	273	...	...	...	...	...	...
15a. Buckerell	*25*	...	103	...	...	...	...	108	103	123	...	...
15b. Colyford	...	113	93	...	...	...	...	...	103	123	150	...
15c. Lyme Regis	1	...	103	...	...	290	53	96	94	103	166	64
17† Combe Martin	1	87	99	...	144	...	11	103	...	124	...	...
18a. Weymouth	4	102	113	...	...	301	50	93	118	146	...	91
19c. Bradney	1	99	114	...	...	282	59	102	...	...	...	57
19f. Staplegrove	2	112	101	96	...	...	59	117	95	113	...	59
19g. West Buckland	...	97	110	114	...	274	...	...	...	...	...	...
20a. West Porlock	11	95	118	109	142	292	...	93	100	129	*180*	99
21c. Sturminster Marshall	1	95	103	112	128	...	...	...	...	...	...	...
21d. Broadstone	2	101	100	119	...	274	...	...	116	...	*182*	...
22a. Pulham	...	102	103	109	148	287	...	...	...	149	...	...
22c. Street	1	96	102	99	...	...	...	...	...	...	...	65
22d. Bruton	1	109	88	...	...	...	37	*148*	...	146	166	86
24a. Blandford	*25*	104	105	103	140	280	...	...	...	...	...	55

* Combination of the three stations 5a, b, c.
† Combination of the three stations 17a, c, d.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued.*

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
25b.	Flax Bourton	5	97	104	112	*114*	279	32	96	97	100	144	*112*
25c.	Keynsham	4	109	97	120	124	277	53	86	92	141	173	72
27c.	Portishead	1	103	113	125	...	276	53	*150*	*99	136	162	56
28b.	Clevedon	3	101	92	114	...	306	*88*	53	112	*154*	...	95
28c.	Cardiff	2	116	...	...	...	278	54	91	100	...	...	...
28d.	Llandaff	4	†98	112	112	...	289	...	...	...	...	...	...
28e.	St. Fagans	...	104	113	...	130	310	76	102	102	124	*178*	69
29a.	Bridgend	5	107	106	...	...	272	55	*138*	*121*	137	143	92
30a.	Mumbles	1	111	114	...	140	303	12	87	93	123	170	100
32a/b.	Tenby	2	102	95	...	...	303	33	93	96	124	166	107
33a.	St. Davids	*25*	94	*137*	...	...	*260*	*114*	106	99	*163*	*176*	74
34c.	Philadelphia	12	99	95	...	...	292	*103*	*141*	98	104	141	*128*
36a.	Llandilo	10	99	118	...	138	304	...	...	...	...	...	...
40a.	Abergavenny	1	...	‡103	...	...	...	...	72	102	114	...	...
43a.	Hafod	*29*	109	115	...	...	268	84	93	92	*94*	*183*	93
43c.	Aberystwyth	5	94	107	...	141	286	39	101	100	100	162	71
	B (10).												
6a.	Timoleague	1	103	118	...	137	293	*104*	111	103	103	157	103
14a.	Monkstown	2	109	...	...	...	272	...	...	...	...	...	*154*
14b.	Passage West	11	115	114	...	...	263	*107*	...	99	115	...	...
22b.	Castle Lyons	1	103	117	...	136	274	67	78	101	114	170	*122*
27a.	Castleconnell	21	102	118	...	141	266	*114*	87	102	102	172	100
30a.	Cashel	21.	100	120	...	...	263	94	*128*	98	141	172	72
34b.	Kilkenny	1	98	114	...	138	275	*1*	100	92	117	129	72
34d.	Freshford	10	100	118	...	...	283	...	100	...	123	...	...
38a.	Mt. Leinster	...	*141*	119	...	...	271	...	*124*	103	141	...	...
38c.	Enniscorthy	3	110	115	...	...	283	60	100	110	130	163	102
38b.	Borris	...	81	124	...	...	278	...	...	101	103	*122*	...
43a.	Mountmellick	4	102	101	...	147	275	94	...	94	103	153	118
50a.	Johnstown Bridge	26	99	119	...	...	285	77	*128*	103	122	...	71
	C (5).												
1§	Bournemouth	36	92	105	110	139	311	56	99	103	...	...	57
1j.	Southbourne	1	103	101	103	...	309	51	94	102	...	...	*163*
1b.	Ringwood	1	*83*	103	103	136	302	50	69	93	119	176	...
1c.	Lymington	2	97	101	100	145	305	55	103	*74*	133	174	91
1i.	Appleslade	6	109	107	...	142	305	37	74	123	103	177	61
1d.	Totland Bay	...	97	103	...	...	328	...	...	...	...	...	...
3a.	Shanklin	3	99	103	110	*118*	314	55	105	102	127	168	...
3e.	Southsea	1	114	104	114	134	298	*99*	*129*	95	145	145	71
3g.	Newport	12	99	100	103	*167*	305	11	74	92	132	167	55
4b.	Sherfield English	44	94	98	104	135	287	10	42	99	109	149	84
4c.	Salisbury	37	100	118	...	132	284	59	92	103	...	...	96
5b.	Holt	3	96	105	...	136	296	24	...	...	...	...	...
5d.	Bratton	1	103	102	...	...	274	...	95	...	95	...	59
5e.	Steeple Ashton	...	94	98	...	128	293	...	...	...	...	...	...
6a.	Havant	37	99	92	111	134	318	47	84	99	134	...	68

* Observed near Taunton. † near Gloucester. ‡ Observed 7 miles North.
§ Combination of the three stations 1a, e, f.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly	Meadow-Brown Butterfly.	Humble Bee
6c. Chichester .	2	97	98	...	...	327	53	55	95	130	140	56
6d/e. Hayling Island	1	103	112	108	...	309	20	68	92	121	179	66
7a. Botley . .	1	87	97	105	128	273	1	54	80	121	176	55
7b. West Meon .	10	102	103	...	...	269	44	59	113	124	55	91
7c. Hythe, Shampton .	4	91	101	114	133	316	71	150	114	121	165	79
7f. Sutton Scotney	...	97	97	118	123	313	...	91	103	...	...	55
7h. Winchester .	1	97	104	...	...	315	29	91	96	...	...	78
8b. Marlborough .	6	91	106	...	134	309	53	26	123	123	165	33
10b. Hove .	1	102	98	...	129	...	69	92	103	121	165	72
10e. Littlehampton	28	111	92	...	...	268	93	...	107	130	145	96
11b. Newton Valance	29	...	102	121	132	265	55	72	...	...	...	73
11c. Haslemere* .	...	103	97	117	132	...	...	...	...	...	...	...
14a. Seaford .	1	...	109	...	...	293	...	...	...	...	171	...
15b/d. Horsham .	2	101	97	107	...	278	24	89	92	102	150	96
15c. Steyning .	...	101	...	...	...	...	...	93	95	103	177	86
16b. Farnham .	2	92	108	99	...	269	...	...	...	...	...	...
16f. Odiham ...	...	...	99	100	...	...	53	96	100	129	193	102
16g. Rowledge .	1	104	96	104	...	...	39	57	...	94	...	111
16i. Churt .	11	99	101	112	...	...	44	74	100	129	174	100
16m. Godalming .	...	101	97	113	...	291	55	121	91	95	...	53
18a. Lewes . .	1	98	100	102	133	326	...	...	100	121	177	95
18b. Hellingly .	...	105	92	102	...	305	...	...	...	...	...	93
18c. Ditchling .	14	112	106	123	137	297	61	85	110	121	171	104
20a. Reading .	9	104	102	113	...	304	55	67	93	141	181	93
20c. Maidenhead .	...	97	107	108	...	...	...	...	103	109	...	58
21b. Hastings .	...	99	96	103	...	...	...	...	...	...	...	...
21c. Burwash .	...	...	98	110	...	277	...	...	...	...	...	...
21d. Rye .	2	103	107	113	135	306	53	55	102	...	185	72
22a. Lingfield .	2	114	100	121	164	320	...	93	96	108	176	82
22b. Warlingham .	...	97	108	...	...	...	46	66	102	...	...	61
22c. Purley . .	1	103	106	...	153	254	53	80	95	...	183	86
22e. Limpsfield .	...	110	109	107	...	...	...	...	...	...	...	...
22f. Penshurst .	...	107	102	...	...	...	55	...	...	102	...	...
24a. Lympne .	2	112	111	112	...	...	...	...	...	...	...	...
24b. Woodchurch .	2	111	97	106	146	316	...	55	99	95	169	131
25a Maidstone .	5	108	92	108	...	276	...	...	102	...	...	95
25b. Mereworth .	2	121	96	124	116	286	57	91	95	103	184	94
26a. Bromley .	...	117	95	...	...	...	57	55	100	...	...	...
27a. Whitstable .	...	104	112	...	...	272	...	...	91	...	...	85
28a. Rochester .	2	103	96	117	127	309	65	119	103	119	...	66
29a. Ash, Sandwich	...	105	108	...	...	274	49	87	98	...	...	...
D (4).												
3d. Longhope .	10	108	109	...	134	271	56	...	95	90	...	...
4a. Weobley .	29	120	99	...	...	290	52	...	100	137	92	57
4b. Staunton-on-Arrow	5	106	97	...	143	284	56	92	100	103	178	76
5d. Coaley . .	5	98	102	123	141	301	71	102	107	108	166	92
5e. Churchdown, Gloucester .	...	105	108	124	...	...	...	...	...	103	...	...

* Received too late for inclusion in means.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued*.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey-Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
5f. Cheltenham .	25	99	94	113	120	272	59	95	103	103	167	61
6a. Dymock .	5	103	98	...	*148*	295	...	97	95	96	...	*142*
6b. Bromyard .	33	109	106	...	...	270	46	*203*	...	...	...	...
10b. Evesham .	1	...	...	118	...	320	...	...	...	...	...	...
10c. Ashorne .	26	104	105	...	...	275	32	67	*73*	...	...	82
11a. Tenbury .	2	97	102	123	131	290	72	92	102	103	176	*136*
14a/b Oxford .	2	101	102	124	...	270	47	...	93	...	...	73
15c. Stratford-on-Avon	2	104	106	*116*	135	272	59	92	93	145	161	126
16b. Cookley, Wolverley .	2	102	109	131	*152*	289	57	...	93	...	...	...
16c. Barnt Green .	30	93	99	...	116	...	28	94	...	108	...	...
16e. South Birmingham	1	109	103	...	133	287	56	...	123	144	180	...
16f. Frankley .	...	104	103	...	...	280	...	...	...	...	...	...
18a/b. Oswestry .	...	103	86	...	132	296	...	86	101	123	175	...
19b. Granborough .	1	97	112	...	132	306	52	96	94	121	181	72
19d. Weston Turville .	...	101	110	...	...	289	...	...	...	...	178	66
20a. Farnborough .	5	110	105	...	140	271	46	*123*	102	124	172	66
21b. Erdington .	5	101	116	...	...	...	*110*	...	93	...	...	...
21d. Hampton-on-the-Hill	5	101	107	...	...	...	56	107	...	...	...	...
21h. Leamington .	2	103	107	124	142	286	29	55	...	146	*108*	95
24a. Bletchley .	1	107	108	107	...	275	61	...	108	126	155	...
24b. Northampton .	9	105	110	...	...	300	55	80	...	...	...	...
26b. Sutton Coldfield .	1	104	...	...	*154*	283	...	...	103	...	...	...
28a. Little Harrowden .	11	94	100	114	132	267	51	55	107	...	...	...
33d. Ketton . .	...	102	111	*139*	...	...	53	...	95	140	...	...
34a. Kegworth .	9	112	110	...	...	290	56	90	102	141	153	86
35a. Somershal Herbert .	28	97	114	...	122	...	59	100	110	142	181	122
35b. Matlock. .	18	109	111	...	128	274	...	...	...	...	...	...
38a. Hodsock .	29	100	118	...	...	315	...	95	100	144	*193*	...
39c. Thurlstone .	27	113	120	...	...	271	58	...	103	...	...	120
39d. Sheffield .	2	109	122	...	...	282	91	57	136	*156*	...	94
41d. Crosshills .	4	93	124	...	...	274	...	*145*	*142*	...	...	5
44a. Sitwell Vale .	6	*141*	*130*	...	...	278	93	...	95	...	...	90
44b. Newhill, Wath	*52*	97	93	...	...	282	55	...	93	...	...	...
44e. Harlington .	36	111	108	...	...	269	...	...	...	...	...	104
45a. Overton .	30	100	109	...	...	260	84	37	128	...	...	...
49b. Fairburn .	37	104	115	...	...	301	...	...	...	...	...	...
E (3)												
1* Barnet . .	4	100	107	117	126	296	...	92	93	129	164	92
2a. Berkhamsted	5	92	104	107	137	...	54	95	95	129	...	...
2b. Tring .	33	103	103	111	130	322	55	104	109	104	*133*	60
4b. Knebworth .	40	104	100	109	...	292	33	30	*61*	145	160	95
4c/l. Harpenden .	1	98	95	120	125	283	50	92	...	144	166	...

* Combination of the three stations 1b, c, d.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued*.

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
4i. Hitchin	1	98	100	98	134	308	45	...	94	...	...	73
4j. Welwyn	*64*	118	116	114	...	...	54	...	100	...	...	...
4k. Pirton, Hitchin	1	103	114	104	...	313	43	91	91	108	180	74
4m. Luton	...	106	108	...	...	289	...	...	...	129	...	...
5a. Turvey	2	97	93	108	136	293	48	94	95	135	167	74
7a. Birch Green	23	95	98	101	133	298	44	76	102	119	163	49
7b. Sawbridgworth	2	98	101	109	131	301	32	96	94	103	167	63
8* Letchworth	1	98	100	98	134	283	44	86	89	...	150	101
8e/f Kempston	1	101	106	...	129	306	54	...	94	120	181	67
10b. Halstead	3	110	108	...	...	272	54	...	...	144	144	72
10e. Braintree	2	103	108	...	...	...	50	96	*127*	141	...	...
10f. Great Totham	27	101	106	108	123	326	37	45	102	116	179	56
11d. Cambridge	2	97	112	122	142	305	46	92	92	120	...	100
13a. Lexden	6	100	103	103	135	299	53	67	94	140	176	...
14a. Ballingdon	1	103	104	105	...	285	60	*122*	93	142	181	102
14c. Sudbury	...	102	110	...	...	291	...	...	...	116	...	...
17b. Ipswich	...	...•	120	109	...	...	...	93	94	...	...	99
17e. Boxford, Colchester	1	108	107	117	140	...	43	93	118	118	...	108
22b. Langford	26	101	103	102	...	291	58	94	103	140	178	*134*
22c. Methwold	5	94	104	109	...	...	...	28	...	...	...	...
22d. Grimston, Lynn	12	100	95	122	...	307	47	...	94	...	...	...
24b. Postwick	26	104	101	105	...	268	57	95	94	128	183	58
25a. Hunstanton	5	102	103	...	...	307	51	...	102	...	145	51
27c. Cromer	10	105	101	120	...	283	75	113	111	...	...	92
28a. Ingham	...	100	108	...	135	...	...	102	...	135	...	...
F (7)												
9a. Beaumaris	9	103	124	...	*155*	...	74	109	119	131	...	103
9b. Deganwy	10	105	117	...	138	275	...	...	...	...	...	...
11d. Trefnant	6	99	113	...	...	291	87	115	*87*	*96*	†*100*	...
13c. Higher Tranmere	4	108	*143*	...	...	274	*93*	93	94	...	...	105
13d. Shotwick	31	110	114	...	...	285	64	...	94	...	179	*142*
14a. Barnton	5	94	110	127	...	273	75	95	108	131	*197*	...
14b. Altrincham	16	115	116	...	134	266	*93*	92	102	126	...	95
16a. Prestbury	6	111	115	...	...	...	59	90	118	...	...	87
16b. Bramhall	7	97	113	...	134	282	56	102	110	...	...	110
19a. Stockport	10	120	122	...	134	273	56	107	122	137	164	...
21a. Leyland	2	100	124	...	...	273	...	...	...	...	183	...
22a. Urswick	32	94	115	...	138	288	74	...	119	119	183	*139*
22b. Ulverston	2	115	128	...	138	...	...	...	...	...	...	...
25a/b. Ambleside	13	92	114	...	122	285	59	99	94	135	...	100
25c. Windermere	5	122	123	...	...	271	...	...	...	...	...	...
28b. Johnby Hall	48	112	132	...	...	289	*133*	...	137	...	...	...
28c. Mungrisdale	33	121	111	...	133	271	...	...	...	...	...	...

* Combination of the three stations 8a, b, c.
† Observed at Rhudlan, six miles N.W.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued.*

	STATION.	BIRDS.						INSECTS.					
		Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
	G (9)												
18a.	Farragh	10	113	115	...	...	277	89	97	103	128	...	...
35c.	Warrenpoint	2	90	113	...	*113*	315	...	95	*76*	109	*108*	67
35d.	Rostrevor	13	103	122	...	...	...	*99*	74	100	136	...	103
41a.	Bessbrook	...	96	...	...	120	273	...	97	108	121	...	98
45a.	Saintfield	...	99	123	...	...	264	...	...	113	...	...	76
47a.	Sixtowns	...	113	118	...	...	273	...	110	110	123	...	...
48b.	Altnafoyle*	4	117	126	...	...	269	...	115	102	117	184	...
50a.	Hillsborough	5	101	101	...	...	267	...	95	113	...	...	137
50c.	Belfast	3	102	120	...	...	290	...	80	100	...	163	...
50d.	Muckamore	20	97	122	...	...	277	...	111	111	...	...	...
50f.	Woodbourne	30	100	109	...	137	272	...	106	*137*	134	171	108
51a.	Magherafelt	8	116	121	...	...	269	60	88	*79*	141	160	...
54a.	Hazelbank	3	100	110	...	...	282	69	99	105	130	157	111
0a.	Douglas, Isle of Man†	2	98	113	...	135	296	...	...	...	...	...	...
	H (6).												
1a.	Drummore	30	122	123	...	...	273	59	105	111	130	150	111
2a.	Marks	26	110	111	...	...	261	...	122	119	...	...	97
12a.	Moniaive	...	118	123	...	...	284	...	...	128	...	...	...
33a.	Ledaig	11	117	122	...	144	273	69	110	117	...	...	...
	I (2).												
6a.	Lincoln	2	108	122	...	136	273	60	104	...	128	...	*59*
9a.	Ashby	26	110	106	127	...	293	73	59	*69*	...	...	74
10a.	West Keal	28	110	119	...	143	273	53	119	...	149	179	106
11c.	Weelsby	11	‡100	108	...	‡136	282	...	...	...	143	...	...
11d.	Cleethorpes	14	103	109	...	...	...	44	92	105	...	...	...
12a.	Holderness	7	105	105	...	*156*	275	*31*	*146*	...	...	...	*59*
18a.	Middleton-in-Teesdale	47	103	121	...	141	273	87	100	134	...	*95*	*133*
19a.	Haltwhistle	32	107	124	...	...	283	74	98	...	128	...	...
20a.	Louth	...	118	101	...	*157*	325	...	108	92	...	185	94
21a.	Hull	5	116	124	...	...	300	*98*	120	112	145	171	98
23a.	Thirsk	24	115	111	...	...	276	58	...	108	136	...	...
24b.	Darlington	9	89	122	...	139	285	46	87	94	131	178	§59
25a/c.	Corbridge	32	106	116	...	...	265	59	92	...	...	...	107
25b.	Stocksfield	47	122	129	...	...	268	...	...	...	...	...	...
25d.	Allendale	...	122	96	...	...	...	55	*141*	*143*	...	...	87
26a.	Catcleugh	34	103	121	...	149	272	...	103	97	...	...	...
27a.	Withernsea	*52*	105	106	...	...	279	56	...	*159*	157	...	110
33a.	Lanchester	28	117	119	...	...	266	55	...	102	*91*	...	114
33b.	Chopwell	29	107	122	...	127	277	55	55	95	...	170	91

* Received too late for inclusion in means. † Not included in the means of District H. ‡ Observed at Brocklesby 11 miles West. § At Brignall 18 miles West.

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TABLE IX.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1926—*continued.*

STATION.	BIRDS.						INSECTS.					
	Song Thrush First Heard.	Swallow First Seen.	Cuckoo First Heard.	Nightingale First Heard.	Flycatcher First Seen.	Swallow Last Seen.	Honey Bee At Flowers.	Queen Wasp On Wing.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow-Brown Butterfly.	Humble Bee.
33c. Chester-le-Street	*60*	120	128	...	...	...	56	103	...	...	103	...
36a. Seaton Delaval	32	107	124	...	...	...	...	...	95	...	...	...
38a. Falloden	10	104	132	...	133	311	55	97	...	...	181	92
38b. Waren Belford	31	104	118	...	...	305	*35*	103	93	*100*	...	94
38c. Lemmington	31	109	125	...	149	280	59	91	*136*	137	171	74
39a. Berwick	4	110	128	...	...	266	75	75	...	...	...	*124*
J (1).												
2a. Broughton	34	109	120	...	120	266	74	106	139	...	...	...
4a. Selkirk	6	94	121	...	136	292	...	...	...	...	...	...
6a. Gattonside	...	112	...	...	...	264	51	102	105	...	...	94
10a. West Foulden	32	104	130	...	152	315	...	110	110	...	175	...
13a. Stirling	13	108	...	...	*115*	263	59	100	131	...	...	84
13c. Gargunnock	47	105	113	...	...	262	53	102	110	108	*199*	80
15a. Duntermline	24	106	134	...	...	254	*101*	...	138	...	...	...
20a. Loch Tummel	29	109	120	...	147	...	...	101	131	...	...	97
21a. Dundee	*64*	108	104	...	...	...	45	72	102	...	...	...
36a. Cabrach	37	124	119	...	138	270	66	103	100	107	146	102
36b. Aberlour	...	...	114	...	...	...	32	100	...	123	...	*123*
38a. Murtle	32	121	...	...	...	299	53	...	...	...	...	73
39a. Dunlugas	41	110	121	...	...	273	55	102	109	119	148	75
39b. Forglen	12	107	137	...	144	290	49	107	109	...	101	95
39c. Huntly	45	121	130	...	...	*272	...	102	122	...	...	...
40a. Cullen	30	127	129	...	...	...	55	111	106	...	...	...
40b. Kellas	...	*143*	120	...	...	...	54	98	101	...	...	95
K (0).												
24b/c. Muir of Ord	29	109	118	...	150	...	51	...	102	142	...	...
26a. Aviemore	55	124	123	...	...	...	74	121	†97	...	...	75
27b. Kirkhill	21	127	120	...	129	265	74	*143*	121	...	...	74
33a. Golspie	32	124	121	...	...	...	...	...	122	...	...	95
Total Records Used	257	344	351	97	113	234	191	176	221	163	104	103

* Observed at Fochabers 18 miles West.
† Observed on Black Isle, Ross-shire.

(*Continued from page* 275.)

Other Vertebrates. Vipers seen as early as Feb. 24, A17c, and as late as Oct. 13 (A5c, killed, two or three feet long) and Dec. 10. (A17c). B6a, reports growing scarcity of frogs; no spawn seen for years. F22a, also very scarce and toads scarcer from the mines lowering the water table. E28b, toad spawn, March 7. J36a, usually no frog spawn till April.

(Note that with 1926 tabulation of frog spawn is begun; see Table IV., last column.)

(*Continued on page* 290.)

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TABLE X.—MEAN DATES (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS IN 1926, AND DIFFERENCE FROM THE AVERAGE OF THE 35 YEARS, 1891—1925.

BIRDS AND INSECTS.	Channel Islands 1926.	A (8) England, S.W.			B (10) Ireland, S.			C (5) England, S.E.			D (4) England, Mid.			E (3) England, E.			F (7) England, N.W.		
		1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.
1. Song Thrush First Heard	1	4	15	−11	10	12	− 2	8	14	− 6	13	19	− 6	9	16	− 7	16	24	−8
2. Swallow First Seen	105	101	105	− 4	101	105	− 4	102	105	− 3	104	109	− 5	103	109	− 6	105	110	−5
3. Cuckoo First Heard	106	108	111	− 3	115	116	− 1	102	107	− 5	108	112	− 4	106	111	− 5	117	117	0
4. Nightingale First Heard	...	111	120	− 9	...	...	...	100	112	− 3	120	117	+ 3	109	114	− 5	[127]	122	[+5]
5. Spotted Flycatcher First Seen	(129)	137	134	+ 3	140	135	+ 5	134	132	+ 2	132	135	− 3	132	135	− 3	133	131	+2
6. Swallow Last Seen	310	290	282	+ 8	274	279	− 5	205	202	+ 3	283	282	+ 1	294	289	+ 5	277	279	−2
Mean of Nos 2, 3 and 5	113	115	117	− 2	119	119	0	113	115	− 2	115	119	− 4	114	118	− 4	118	119	−1
7. Honey Bee at Flowers	[52]	50	58	− 8	74	61	+13	48	56	− 8	58	59	− 1	49	53	− 4	66	65	+1
8. Queen Wasp on Wing	[104]	90	96	− 6	97	99	− 2	76	94	−18	84	101	−17	86	94	− 8	100	105	−5
9. Small White Butterfly	94	101	102	− 1	101	108	− 7	100	103	− 3	103	112	− 9	98	107	− 9	112	114	−2
10. Orange-Tip Butterfly	[103]	123	127	− 4	118	121	− 3	119	127	− 8	123	133	−10	128	132	− 4	129	136	−7
11. Meadow Brown Butterfly	159	157	160	− 3	159	146	+13	160	164	+ 5	171	167	+ 4	167	167	0	173	170	+3
12. Humble Bee	...	76	...	...	93	...	...	81	...	...	86	...	...	81	...	...	100	...	...
Mean of Nos. 7-11	102	104	109	− 5	110	107	+ 3	102	109	− 7	108	114	− 6	106	111	− 5	116	118	−2

BIRDS AND INSECTS.	G (9) Ireland, N.			H (6) Scotland, W.			I (2) England, N.E.			J (1) Scotland, E.			K (0) Scotland, N.			England and Wales.*			British Isles.†		
	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.	1926.	Average 35 years.	Difference from Average.
1. Song Thrush	10	20	−10	22	29	− 7	24	30	− 6	30	28	+ 2	36	41	− 5	12	19	− 7	17	23	− 6
2. Swallow First Seen	102	108	− 6	117	113	+ 4	109	114	− 5	111	118	− 7	122	126	− 4	104	109	− 5	107	111	− 4
3. Cuckoo	115	118	− 3	122	120	+ 2	117	119	− 2	122	123	− 1	121	125	− 4	110	113	− 3	114	116	− 2
4. Nightingale	...	120	...	...	...	...	[127]	120	[+7]	...	...	...	...	...	...	117	117	0	‡121	‡125	− 4
5. Spotted Flycatcher	(128)	137	(− 9)	[144]	140	[+4]	139	135	+ 4	130	139	0	(139)	158	(−19)	135	134	+ 1	136	137	− 1
6. Swallow Last Seen	278	275	+ 3	273	275	− 2	282	279	+ 3	276	270	+ 6	[265]	260	[+5]	287	284	+ 3	281	278	+ 3
Mean of Nos. 2, 3 and 5	115	121	− 6	128	124	+ 4	122	123	− 1	124	127	− 3	127	136	− 9	116	119	− 3	119	121	− 2
7. Honey Bee	73	73	0	(64)	72	(− 8)	60	64	− 4	57	68	−11	67	66	+ 1	55	59	− 4	61	63	− 2
8. Queen Wasp	96	109	−13	112	121	− 9	95	111	−16	101	117	−16	(107)	120	(−13)	89	100	−11	95	106	−11
9. Small White Butterfly	107	115	− 8	119	124	− 5	104	119	−15	116	129	−13	111	134	−23	103	109	− 6	107	115	− 8
10. Orange-Tip Butterfly	128	130	− 2	[130]	131	[− 1]	138	143	− 5	114	151	−37	[142]	*148*	[− 6]	127	133	− 6	127	135	− 8
11. Meadow Brown Butterfly	166	165	+ 1	[150]	167	[−17]	176	167	+ 9	157	175	−18	...	*172*	...	169	167	+ 2	165	165	0
12. Humble Bee	100	...	...	(104)	...	...	95	...	...	90	...	...	83	...	...	87	...	...	90	...	...
Mean of Nos 7-11	114	118	− 4	115	123	− 8	115	121	− 6	109	128	−19	...	128	...	109	114	− 5	111	117	− 6

* Average of districts A, C, D, E, F, I. † The British Isles means in both Tables X. and XI. are the means of the separate districts. ‡ The difference between the dates for the Nightingale and the Cuckoo in those districts in which *both* have been recorded, has been used as a basis for deriving the British Isles means for Nightingale. Values given above in *italics* have been interpolated owing to lack of data and are approximate only.

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TABLE XI.—Arrival of Spring Migrants, 1926.

Stations. (129 selected out of about 300 of our observers, besides over 100 from periodicals.)	Mean Value.*	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucos*).	House Martin (*Chelidon urbica*).	Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Nightjar (*Caprimulgus europæus*).	Mean of Nos. 1 to 5.	Mean of Nos. 6 to 12.	Mean of Nos. 13 to 20.
		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
A of† Guernsey . .	108.9	71	74	93	*98*	*102*	*108*	*110*	*106*	110	*112*	*117*	111	120	131	134	*138*	86.2	107.3	124.6
oe Jersey . .	106.6	77	*90*	*95*	91	94	91	*110*	106	*106*	*112*	*117*	96	111	*123*	116	*138*	93.4	104.9	116.4
5‡ Polperro . .	110.5	78	*90*	94	93	91	*109*	*110*	108	103	*114*	118	*122*	*122*	127	*125*	*138*	91.2	107.6	125.0
6c. Lopwell . .	113.5	94	94	101	102	*103*	102	111	108	111	120	*119*	*122*	130	123	123	130	102.0	109.3	124.3
14a. Umberleigh .	109.9	82	*90*	*97*	81	*103*	*109*	*110*	104	*107*	*114*	*119*	*122*	120	*123*	*125*	146	89.6	106.0	126.1
15b. Colyford . .	113.9	103	*90*	103	103	*103*	*109*	110	123	*107*	*114*	120	*122*	123	132	*125*	*138*	102.4	108.4	126.0
17§ Combe Martin .	109.2	84	87	93	*99*	*103*	*109*	*110*	97	*107*	*114*	*119*	*122*	119	117	*125*	*138*	90.0	105.6	124.4
20a. West Porlock .	111.7	84	84	90	92	*103*	111	119	112	107	*114*	*119*	124	122	*123*	*125*	141	89.0	112.0	125.6
21c. Sturminster Marshall .	109.0	74	*90*	93	95	*103*	102	103	95	108	109	*119*	*122*	133	*123*	132	141	89.4	103.3	126.3
22c. Street . .	110.3	87	87	101	*99*	*103*	*109*	*110*	*108*	*107*	114	*119*	*122*	121	*123*	*125*	*138*	94.0	107.6	123.0
24a. Blandford .	110.3	83	81	95	*99*	*103*	110	*110*	113	111	113	*119*	*122*	119	*123*	121	131	92.4	109.3	122.3
25c. Keynsham .	108.3	96	*90*	96	90	88	101	124	92	91	111	*119*	*122*	110	*123*	*125*	*138*	96.2	100.6	122.6
25g. Butcombe .	107.8	92	*90*	100	92	*103*	95	102	92	97	98	*119*	*122*	*122*	*123*	*125*	*138*	94.2	98.3	124.6
27c. Portishead.	113.1	88	*90*	*97*	108	*103*	*109*	*110*	116	*107*	*114*	*119*	*122*	122	120	122	*138*	97.2	110.3	125.6
28b. Clevedon .	111.3	93	94	93	*99*	*103*	105	*110*	113	*107*	120	*119*	*122*	118	*123*	*125*	*138*	96.0	107.1	124.5
28d. Llandaff .	111.9	87	*90*	100	¶105	*103*	112	*110*	*108*	*107*	*114*	*119*	*122*	116	*123*	*125*	*138*	96.0	109.4	124.0
28e. St. Fagans .	112.8	*87*	*90*	99	97	*103*	122	*110*	121	105	*114*	125	*122*	110	*123*	*125*	*138*	95.4	112.0	123.9
32a. Tenby . .	110.9	105	*90*	105	94	*103*	*109*	*110*	94	105	*114*	112	*122*	123	*123*	*125*	*138*	99.2	104.3	123.9
36a. Llandilo .	110.3	78	80	93	99	114	103	104	*108*	*107*	*114*	118	116	119	*123*	*125*	*138*	89.8	109.7	123.5
43c. Aberystwyth .	111.9	85	76	94	92	115	119	106	*108*	115	123	120	*122*	117	125	*125*	144	88.2	113.3	125.6
B 6a. Timoleague .	112.1	83	*91*	95	96	*104*	*110*	*111*	113	*110*	*116*	125	*123*	123	108	*125*	137	93.6	111.7	123.9
22b. Castle Lyons .	113.5	92	*91*	102	*100*	*104*	*110*	*111*	112	*110*	*116*	*121*	*123*	131	117	*125*	*137*	97.6	111.4	125.4
27a. Castleconnell .	113.4	89	*91*	102	96	*104*	*110*	*111*	*113*	*110*	*116*	*121*	*123*	120	‖126	*125*	*137*	96.0	111.7	125.7

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		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
C 1** Bournemouth .	108.4	86	76	93	95	*101*	92	*107*	111	114	*114*	114	117	123	*128*	118	*132*	88.4	106.3	122.6
1j. Southbourne .	108.6	92	77	96	82	*101*	99	*107*	*111*	103	117	113	124	121	*128*	128	*132*	90.0	105.6	122.9
1b. Ringwood . .	106.0	88	84	91	82	*101*	97	*107*	96	104	108	96	112	116	124	131	139	89.4	102.3	119.6
1c. Lymington .	109.8	94	*86*	103	101	*101*	*105*	*107*	102	108	116	*111*	*114*	117	*128*	*127*	*132*	96.2	105.7	121.8
1i. Appleslade . .	113.0	87	93	93	*105*	103	112	*107*	*111*	111	*114*	119	125	121	*128*	125	138	97.4	109.3	125.9
3a. Shanklin . .	110.6	89	85	93	102	100	119	*107*	102	106	120	121	*114*	123	*128*	127	130	93.6	108.1	123.4
3e. Southsea . .	111.6	104	96	97	*105*	104	104	10‡	*111*	104	104	124	104	123	117	132	*132*	103.2	105.0	122.5
4b. Sherfield English.	110.3	83	*86*	93	*105*	*101*	121	*107*	125	107	*114*	*111*	*114*	121	131	123	*132*	92.2	110.4	121.4
5b. Holt . .	109.6	83	*86*	99	*105*	*101*	*105*	*107*	108	113	*114*	102	*114*	122	*128*	*127*	*132*	93.8	107.6	121.3
5e. Steeple Ashton .	109.7	85	*86*	95	128	*101*	*105*	*107*	120	104	106	*111*	*114*	118	*128*	125	*132*	97.6	105.9	120.6
6a. Havant . .	110.1	91	84	91	99	93	119	*107*	108	104	111	*111*	119	122	131	126	149	92.8	104.9	125.4
6d/e. Hayling Island	110.6	96	*86*	93	*105*	*101*	*105*	*107*	*111*	*107*	*114*	*111*	*114*	130	*128*	*127*	120	96.6	108.1	121.5
7a. Botley . .	106.3	87	*86*	95	93	109	98	*107*	109	97	*114*	*111*	100	103	*128*	125	*132*	92.6	104.4	116.5
7c. Hythe . .	110.2	87	90	100	*105*	102	*105*	*107*	103	112	119	*111*	123	117	*128*	124	132	94.6	107.0	122.8
7f. Sutton Scotney .	109.1	89	*86*	99	116	*101*	98	*107*	114	99	110	98	*114*	122	*128*	134	*132*	97.4	103.7	121.1
7h. Winchester .	108.5	77	*86*	93	*105*	*101*	94	*107*	107	*107*	*114*	104	*114*	119	*128*	138	*132*	91.6	104.9	122.3
8b. Marlborough .	114.7	88	*86*	101	124	107	121	*107*	124	104	121	122	*114*	121	*128*	134	151	98.0	112.9	126.6
10e. Littlehampton .	110.1	*90*	*86*	*96*	111	*101*	*105*	*107*	130	*107*	114	*111*	*114*	121	122	127	124	98.8	106.6	120.3
11c. Haslemere . .	108.4	67	90	91	103	92	94	124	105	99	112	124	119	122	*128*	117	*132*	90.8	103.3	123.9
15b/d Horsham . .	110.8	92	*86*	99	*105*	*101*	*105*	*107*	118	113	116	*111*	*114*	123	*128*	*127*	*132*	96.6	108.1	122.0
16f. Odiham . .	109.0	93	*86*	98	*105*	*101*	*105*	*107*	92	127	*114*	*111*	94	131	*128*	121	*132*	96.8	106.4	118.9
16g. Rowledge . .	109.5	85	86	92	102	93	111	*107*	123	103	*114*	*111*	*114*	123	*128*	*127*	133	93.8	106.7	121.8
16i. Churt . .	111.6	91	*86*	91	*105*	112	*105*	*107*	*111*	112	*114*	*111*	*114*	134	*128*	132	*132*	94.4	108.9	124.6
16m. Godalming .	110.3	86	*86*	93	117	93	96	117	101	115	118	*111*	120	127	*128*	121	*132*	96.6	105.3	123.3
18a. Lewes . .	107.3	79	86	92	95	93	92	108	120	98	110	108	122	119	*128*	130	*132*	90.0	103.0	121.8
18c. Ditchling . .	110.5	73	96	110	108	*101*	114	*107*	106	106	123	106	110	127	122	113	123	99.8	109.0	118.4
21b. Hastings . .	109.4	*90*	*86*	*96*	112	*101*	*105*	102	113	*107*	103	117	*114*	*123*	*128*	*127*	*132*	96.6	103.9	122.3
21d. Rye . .	111.5	88	90	107	*105*	*101*	111	*107*	117	106	113	104	117	117	*128*	128	*132*	98.6	108.9	121.8

* The *Bird* values are the mean of all actual records (excluding those abnormally early or late), by districts, without any interpolation. The *Station* values are obtained by interpolating for blanks either the district mean, or a considered value from adjacent records. Such values are printed in *italics*. † Combination of three stations 0a, b, d. ‡ Combination of three stations 5a, b, c. § Combination of three stations 17a, b, d. ¶ Observed at Merthyr 20 miles North. ‖Observed at Limerick 7 miles S.W. ** Combination of the three stations 1a, e, f.

NOTE.—For reason of space the following are omitted from the printed table, although included in the station means:—(4) Swallow, (8) Cuckoo, (14) Nightingale, (20) Spotted Flycatcher. They, of course, appear in Table IX.

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TABLE XI.—Arrival of Spring Migrants, 1926—*continued.*

Stations.	Mean Value.	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucus*).	House Martin (*Chelidon urbica*).	Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift. (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Nightjar (*Caprimulgus europæus*).	Mean of Nos. 1 to 5.	Mean of Nos. 6 to 12.	Mean of Nos. 13 to 20.
		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
22a. Lingfield . .	112.0	84	*86*	94	*105*	108	94	*107*	120	*107*	*114*	*111*	119	134	*128*	*127*	*132*	96.6	107.1	125.8
22c. Purley . .	111.1	88	*86*	96	*105*	*101*	106	*107*	118	110	115	*111*	114	*123*	131	*127*	*132*	95.6	109.0	122.6
24a. Lympne . .	111.0	94	*86*	94	*105*	*101*	*105*	*107*	100	*107*	*114*	*111*	*114*	122	*128*	130	*132*	98.2	106.4	122.9
24b. Woodchurch .	111.9	103	*86*	88	*105*	109	*105*	*107*	*111*	*107*	119	*111*	120	122	*128*	131	*132*	98.6	107.9	123.8
28a. Rochester . .	112.2	94	109	93	109	104	113	101	113	114	115	*111*	109	130	*128*	129	*132*	101.6	108.0	122.5
D 4b. Staunton-on-Arrow .	112.0	89	*93*	98	101	*109*	101	*101*	101	104	*114*	*118*	*124*	120	*129*	142	*130*	97.4	103.9	128.3
5d. Coaley . .	114.0	87	92	*99*	120	122	120	*101*	109	103	120	*118*	126	120	125	123	*130*	99.2	111.0	125.8
5f. Cheltenham .	108.3	91	76	96	105	92	*107*	100	114	108	114	114	116	120	124	*133*	*130*	93.4	104.1	121.3
6a. Dymock . .	112.8	89	*93*	108	*107*	*109*	98	*101*	*110*	108	*114*	*118*	*124*	131	*129*	*133*	*130*	100.0	105.4	127.1
11a. Tenbury . .	111.4	88	*93*	91	*107*	117	122	*101*	99	103	105	*118*	122	117	*129*	133	*130*	95.2	107.0	125.4
15c. Stratf'd-on-Avon	113.5	88	*93*	*99*	*107*	*109*	*107*	*101*	112	111	116	*118*	*124*	128	*129*	*133*	*130*	98.2	108.9	127.1
16b. Cookley, Wolverley	113.0	86	*93*	93	*107*	*109*	103	*101*	*110*	107	*114*	*118*	*124*	120	131	139	*130*	96.2	107.0	128.1
16c. Barnt Green .	111.9	91	*93*	92	108	100	*107*	108	108	126	*114*	*118*	*124*	123	*129*	138	*130*	95.4	108.9	124.8
16e. S. Birmingham .	112.7	84	71	109	109	111	112	109	109	111	119	112	130	119	127	127	*130*	96.4	110.1	124.8
18a/b. Owestry . .	112.5	100	*93*	*99*	*107*	106	*107*	108	107	*111*	*114*	*118*	123	121	131	*133*	*130*	100.4	105.6	126.0
19b. Granborough .	112.1	91	*93*	97	*107*	*109*	*107*	*101*	96	111	*114*	*118*	*124*	120	*129*	*133*	*130*	97.0	107.1	125.8
20a. Farnborough .	114.8	87	*93*	*99*	*107*	*109*	*107*	*101*	126	*111*	112	*118*	*124*	130	*129*	138	*130*	99.2	110.1	128.6
21b. Erdington . .	115.6	96	*93*	110	*107*	*109*	*107*	*101*	107	121	*114*	*118*	*124*	129	138	138	*130*	101.4	110.7	128.6
21h. Leamington .	114.0	91	*93*	94	132	101	103	*101*	103	108	*114*	*118*	*124*	123	*129*	139	*130*	102.6	105.3	128.6
26b. Sutton Coldfield .	114.6	92	*93*	92	105	109	*107*	106	*110*	124	*114*	*118*	134	124	*129*	140	*130*	97.4	111.1	128.4
30e. Farley, Alton .	113.2	90	*93*	92	*107*	109	*107*	*101*	103	123	108	*118*	131	*124*	132	*133*	*130*	98.4	107.4	127.5
35a. Somershal Herbert	112.1	88	*94*	97	104	101	111	101	104	105	122	120	127	129	120	*133*	*130*	99.0	108.3	125.4
49b. Fairburn . .	114.8	*91*	*91*	100	101	*110*	*109*	*103*	124	117	*116*	122	115	122	132	126	*130*	99.8	113.4	125.3

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		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
E 1*	Barnet	109.6	87	95	92	*101*	95	101	*113*	111	108	108	*112*	117	122	*129*	*124*	*126*	95.6	106.1	121.6
2a.	Berkhamsted	110.2	89	*89*	95	*101*	*102*	108	*113*	*107*	*109*	123	*112*	*115*	*122*	*129*	123	*126*	93.2	109.4	121.4
2b.	Tring	108.7	*90*	55	*96*	*101*	113	118	*113*	103	110	*114*	*112*	*115*	107	*129*	*124*	*126*	89.6	110.6	119.3
4c/l.	Harpenden	110.7	89	*89*	93	*101*	117	*104*	*113*	120	115	108	*112*	*115*	121	*129*	*124*	*126*	94.0	110.3	121.5
4i.	Hitchin	105.3	86	104	91	89	97	85	*113*	101	104	101	106	102	117	129	124	*126*	93.6	100.1	117.0
5a.	Turvey	109.5	83	72	95	*101*	104	108	*113*	100	119	*114*	119	113	126	*129*	128	*126*	90.6	107.3	123.1
7b.	Sawbridgeworth	109.9	86	93	93	*101*	102	*104*	*113*	*107*	103	*114*	*112*	*115*	130	*129*	130	*126*	94.2	106.3	122.8
7g.	Harlow	110.0	99	*89*	97	100	102	106	*113*	110	*109*	*114*	*112*	*115*	119	*129*	*124*	*126*	96.2	107.4	120.2
8†	Letchworth	105.6	86	104	91	89	97	85	*113*	101	104	101	106	101	112	129	124	*126*	93.6	100.1	116.3
8e/f.	Kempston	108.9	87	*89*	95	101	102	*104*	*113*	101	101	*114*	108	*115*	124	*129*	*124*	*126*	94.6	105.9	120.5
11d.	Cambridge	111.4	89	*89*	94	96	*102*	107	*113*	102	107	128	104	*115*	129	*129*	*124*	*126*	93.0	110.1	123.9
14a.	Ballingdon	113.0	94	*89*	*96*	*101*	106	121	*113*	*107*	*109*	128	*112*	126	130	*129*	129	*126*	96.6	112.6	123.6
22b.	Langford	111.1	94	88	107	97	*102*	*104*	104	104	*109*	116	118	*115*	130	*129*	129	138	97.4	106.0	124.1
22d.	Grimston, Lynn	108.9	*90*	*89*	*96*	*101*	*102*	109	*113*	105	108	*114*	*112*	*115*	105	*129*	115	*126*	95.2	106.6	119.5
25a.	Hunstanton	108.8	51	*89*	*96*	106	102	*104*	*113*	120	*109*	*114*	*112*	*115*	131	*129*	*124*	114	88.8	109.3	120.8
27c.	Cromer	110.9	94	95	95	114	94	*104*	*113*	95	112	118	*112*	*115*	128	*129*	115	*126*	100.6	105.3	122.1
F 9a.	Beaumaris	115.5	87	*93*	97	119	*111*	*115*	*106*	122	*114*	*114*	*120*	*119*	133	115	*130*	*128*	99.8	115.1	125.6
9b.	Deganwy	113.7	86	82	93	108	*111*	*115*	*106*	122	117	*114*	*120*	*119*	122	113	*130*	*128*	94.8	114.6	124.6
14a.	Barnton	109.7	92	*93*	96	94	102	102	105	100	100	101	111	122	129	124	*130*	*128*	93.8	102.9	125.5
14b.	Altrincham	114.1	108	*93*	100	94	*111*	108	*106*	94	115	*114*	120	*119*	130	121	*130*	*128*	102.0	109.1	126.1
16b.	Bramhall	115.1	*93*	95	106	*107*	112	*115*	115	117	116	111	*120*	*119*	122	129	*130*	124	99.6	114.1	125.6
19a.	Stockport	121.0	96	107	*99*	120	*111*	130	*106*	124	129	129	*120*	*119*	136	133	*130*	*128*	108.4	121.6	128.4
22a.	Urswick	114.4	*93*	99	98	*107*	*111*	*115*	*106*	105	*114*	*114*	*120*	*119*	122	133	*130*	*128*	98.2	111..	127.1
22b.	Ulverston	118.9	93	*93*	94	121	*111*	*115*	*106*	127	113	*114*	128	128	128	130	*130*	*128*	103.2	116.3	129.6
25a/b.	Ambleside	111.7	93	93	99	96	112	123	105	99	110	*114*	*120*	115	129	122	*130*	119	94.6	111.6	123.0
28c.	Mungrisdale	116.2	*93*	91	99	*107*	*111*	*115*	109	129	*114*	*114*	*120*	*119*	128	*125*	*130*	*128*	102.2	114.7	126.3
G 35c.	Warrenpoint	112.5	108	*91*	93	95	*105*	*112*	*114*	96	120	*120*	122	*123*	116	117	*125*	140	95.4	111.4	124.1
50f.	Woodbourne	112.0	95	91	93	104	101	*112*	*114*	98	*120*	123	*120*	*123*	115	112	*125*	128	96.6	111.0	122.5
54a.	Hazelbank	112.9	91	*91*	107	100	108	112	117	112	126	*120*	117	*123*	121	116	121	117	97.8	115.0	120.6
H 0a.	Douglas, I. of Man‡	112.0	82	91	92	89	*110*	106	115	*113*	108	*122*	115	*123*	131	117	*125*	*128*	90.2	112.4	125.1
0c.	Ramsey, I. of Man‡	114.1	93	85	96	92	*110*	*113*	122	*113*	*120*	*122*	122	*123*	*126*	114	*125*	134	93.2	116.6	125.1
33a.	Ledaig	122.3	*100*	*100*	120	*105*	119	*115*	*120*	*119*	*125*	*130*	*129*	*131*	133	*125*	*130*	*133*	108.4	121.2	131.9

* Combination of the three stations 1b, c, d.
† Combination of three stations 8a, b, c.
‡ Not included in means of District H.

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TABLE XI.—ARRIVAL OF SPRING MIGRANTS, 1926—*continued.*

STATIONS.	Mean Value.	Chiffchaff (*Phylloscopus rufus*).	Wheatear (*Saxicola œnanthe*).	Willow Warbler (*Phylloscopus trochilus*).	Sand Martin (*Cotile riparia*).	Tree Pipit (*Anthus trivialis*).	Blackcap (*Sylvia atricapilla*).	Sandpiper (*Totanus hypoleucus*).	House Martin (*Chelidon urbica*).	Whitethroat (*Sylvia cinerea*).	Lesser Whitethroat (*Sylvia curruca*).	Sedge Warbler (*Acrocephalus phragmitis*).	Garden Warbler (*Sylvia hortensis*).	Swift. (*Cypselus apus*).	Corncrake (*Crex pratensis*).	Turtle Dove (*Turtur communis*).	Nightjar (*Caprimulgus europæus*).	Mean of Nos. 1 to 5.	Mean of Nos. 6 to 12.	Mean of Nos. 13 to 20.
		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
I 6a. Lincoln	118.9	99	*100*	101	*104*	*119*	121	*113*	126	122	*123*	118	*123*	129	*125*	127	*135*	102.4	120.9	127.5
11b. Thornton Abbey	117.7	92	*100*	101	*104*	*119*	*113*	*113*	130	118	122	118	*123*	130	*125*	134	*135*	101.2	116.6	128.9
11c. Weelsby	117.1	†94	114	98	108	*119*	122	113	108	110	120	108	†122	†128	†138	†133	*135*	102.8	114.3	128.4
12a. Holderness	114.9	*97*	93	95	88	128	117	*113*	100	111	127	110	129	127	126	126	*136*	95.6	114.4	127.4
14a. York	111.9	86	*100*	97	101	*119*	102	101	99	108	*123*	*119*	113	121	123	*130*	*135*	95.8	107.3	125.9
18a. Middleton-in-Teesdale	119.1	*97*	89	102	114	119	*113*	123	122	*117*	*123*	*119*	127	123	136	*130*	*135*	101.0	119.7	129.7
19a. Haltwhistle	116.9	*97*	101	95	101	*119*	*113*	114	*117*	111	*123*	*119*	117	*128*	121	*130*	*135*	100.2	117.3	127.0
21a. Hull	119.1	*97*	*100*	100	104	120	119	115	119	*117*	*123*	119	*123*	130	*125*	*130*	*135*	103.4	119.6	128.5
24b. Darlington	117.6	100	92	98	108	117	114	*113*	123	125	*123*	*119*	*123*	120	135	*130*	*135*	97.4	119.6	128.5
26a. Catcleugh	119.7	106	105	103	*104*	122	*113*	107	110	124	*123*	129	131	*128*	*125*	*130*	*135*	104.2	117.1	131.7
33b. Chopwell	114.5	*97*	102	95	104	112	*113*	117	107	111	*123*	*119*	110	130	110	*130*	128	101.0	115.0	122.6
38a. Falloden	118.3	*97*	101	104	104	*119*	*113*	*113*	*117*	125	*123*	*119*	118	*128*	*125*	*130*	*136*	102.0	120.3	126.9
38c. Lemmington	119.4	94	92	101	115	113	105	117	117	121	124	130	129	124	*125*	*130*	141	102.2	117.4	131.9
39a. Berwick	120.3	*97*	99	101	105	*119*	*113*	114	128	*117*	*123*	133	*123*	130	135	*130*	*135*	102.4	120.3	131.5
J 4a. Selkirk	118.5	*102*	94	109	108	114	*113*	87	129	136	*127*	129	129	124	124	*130*	*135*	101.4	118.1	129.5
10a. West Foulden	119.1	*102*	85	105	100	*110*	*113*	*103*	*119*	*125*	*127*	*129*	*129*	129	*125*	*130*	*135*	99.2	118.1	132.3
20a. Loch Tummel	119.6	*102*	88	103	103	110	*113*	104	121	*125*	*127*	131	*129*	130	*125*	*130*	146	101.0	117.1	133.4
21a. Dundee	115.3	*102*	*95*	*107*	110	*110*	*113*	*103*	111	116	*127*	*129*	*129*	115	107	*130*	121	104.4	112.0	124.9
36a. Cabrach	124.3	108	108	118	120	114	102	107	132	136	138	127	135	140	*125*	*130*	*135*	115.6	121.1	132.4
39a. Dunlugas	117.2	*102*	91	107	102	102	115	115	110	116	*127*	108	*129*	118	138	*130*	*135*	102.4	115.1	128.3
K24b/c. Muir of Ord.	122.7	*106*	*103*	109	116	*113*	*117*	127	107	*127*	*129*	*131*	134	130	129	*132*	*135*	108.6	119.7	134.0
26a. Aviemore	122.1	*106*	*103*	108	107	103	*117*	107	126	*127*	*129*	*131*	*133*	133	*129*	*132*	*135*	109.6	118.9	132.7
27b. Kirkhill	122.8	*106*	106	106	124	123	*117*	106	123	120	126	*131*	*133*	*133*	128	*132*	*135*	113.8	119.3	131.5

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		1	2	3	5	6	7	9	10	11	12	13	15	16	17	18	19			
Total records used = 2648	...	203	94	188	121	82	91	66	165	128	64	61	72	195	104	71	38	...	...	...
Mean of—																				
A (8) England S.W.	111.5	87	90	97	99	103	109	110	108	107	114	119	122	122	123	125	138	94.8	108.4	124.6
B (10) Ireland S. .	112.9	87	*91*	99	100	*104*	*110*	*111*	113	*110*	*116*	[125]	*123*	122	117	*125*	[137]	95.6	111.3	125.3
C (5) England S.E.	110.2	90	86	90	105	101	105	107	111	107	114	111	114	123	128	127	132	95.8	106.7	122.3
D (4) England Mid.	113.2	91	93	99	107	109	107	101	110	111	114	118	124	124	129	133	*130*	98.8	108.6	126.3
E (3) England E. .	110.1	90	89	96	101	102	104	(113)	107	109	114	112	115	122	129	124	(126)	95.8	107.9	121.1
F (7) England N.W.	114.9	93	93	99	107	111	115	106	113	114	114	120	119	128	125	*130*	128	99.4	112.9	126.3
G (9) Ireland N. .	118.5	95	[91]	103	98	(105)	[112]	[117]	110	(123)	[123]	(119)	*123*	124	114	[121]	128	97.4	115.0	122.1
I (2) England N.E.	117.3	97	100	100	104	119	113	113	117	117	123	119	123	128	125	130	(135)	102.0	115.6	128.3
J (1) Scotland E. .	119.9	[108]	95	107	105	110	(109)	103	119	125	[138]	129	(132)	129	125	*130*	(133)	105.2	118.0	130.7
K (0) Scotland N. .	122.5	*106*	103	108	116	(113)	*117*	116	119	[120]	[126]	*131*	[134]	133	129	*132*	*135*	111.0	118.9	133.0
Mean, 1926 . .	115.0	93.1	93.7	101.4	104.2	109.2	109.3	111.3	112.7	116.3	120.0	119.1	122.9	126.2	124.0	126.7	132.1	99.9	113.2	126.0
Day of Month . .		A.25	A. 3	A. 4	A.11	A.14	A.19	A.19	A.21	A.23	A.26	A.30	A.29	My. 3	My. 6	My. 4	My. 7	My12	A. 10	A. 23	My.6
Average 13 yrs., 1914-26	117.3	95.8	96.6	105.6	109.8	111.7	112.5	114.8	116.9	119.3	119.3	121.6	124.0	124.5	124.7	126.8	133.0	103.8	115.8	127.1
„ N.H.J., 1877-96	113.1	94	93	103	106	107	110	117	111	113	118	115	125	125	121	123	129	100.0	112.3	122.1
Diff. from 13 yrs.' Avge.		−2½	−2½	−3	−4	−5½	−2½	−3	−3½	−4	−3	+½	−2½	−1	+1½	−½	0	−1	−4	−2½	−1

† Observed at places within 20 miles of the station.

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TABLE XII.—Arrival of Rarer Spring Migrants.

British Isles Means.	Ring Ouzel (*Turdus torquatus*).	Wryneck (*Iynx torquilla*).	Yellow Wagtail (*Motacilla Raii*).	Redstart (*Ruticilla phœnicurus*).	Reed Warbler (*Motacilla arundinacea*).	Grasshopper Warbler (*Locustella nævia*).	Whinchat (*Pratincola rubetra*).	Wood Warbler (*Phylloscopus sibilatrix*).	Pied Flycatcher (*Muscicapa atricapilla*).	Red-Backed Shrike (*Lanius collurio*).	Mean.
Mean 1926 . .	100.3	103.0	110.0	110.9	122.7	120.1	118.4	120.0	122.0	129.6	115.7
Month and Day .	A. 10	A. 13	A. 20	A. 21	My. 3	A. 30	A. 28	A. 30	My. 2	My. 10	A. 26
Average 13 years. 1914-26 . .	97.1	103.9	113.8	115.8	120.0	120.4	120.8	121.9	125.9	130.1	117.0
Diff. from Average .	+3	−1	−4	−5	+2½	−½	−2½	−2	−4	−½	−1½
Total Records Used .	20	50	48	54	29	29	38	51	23	34	...

(*Continued from page* 282.)

Insects. A very poor honey crop. C7f, not enough for store. C4b, hardly any. Orange Tip generally and Meadow Brown locally scarce. Summer butterflies very scanty, though Meadow Brown locally plentiful. Autumn Vanessidæ common (A33a, five species), especially Painted Lady in some parts; even in C7a, where not seen for years. C1b, Comma common in Avon valley and New Forest. G35c, "more Meadow Brown on April 26 than May 25." Were they frequently destroyed when hatching by the May frosts? K33a, reports more Cabbage Whites than since 1918; Red Admirals most for years. Wasps as a rule scarce, or only pests in Sept. (C4b). So humble bees in many parts. Tortrix trouble greatly lessened; C15b, none.

Pests. Aoe, reports special damage by Whites and Orange Tip because they hatched out so early. G54g, fields nearly or quite cleared by Cabbage caterpillars. Widespread mischief by mildew after the drought, especially on turnips; also gooseberry mildew, celery blight and potato blight (I33a, except Kerr's Pink). Greenfly bad in May.

Summary.

1926 repeated the harm to tree fruits by early warmth preceding late April and May cold, conditions brought out by our tables and charts equally by plants, insects and migrants. Notable were the absence of much effect from the frosts of November-December, 1925; the unusual number of records of early cuckoos and swallows and equally so of late tarrying of swallows and house martins; the year proving good for farmers despite the summer coolness, early summer drought and notable absence of sunshine especially from May to July.

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TABLE XIII.—Additional Bird Records.

District.	First Song.					Cuckoo Last Heard	Autumn Migration.						
	Missel Thrush	Song Thrush	Blackbird	Lark	Mean of Nos. 1-4		Last Swift	Last Sand Martin	Last Swallow	Last House Martin	First Redwing	First Fieldfare	Mean of Nos. 6-11
	1	2	3	4		5	6	7	8	9	10	11	
Channel Isles	(21)	1	24	36	20.5	(181)	247	...	310	286	[311]	...	...
A (8) England S.W.	15	4	23	41	20.7	178	226	282	290	295	290	298	280.2
B (10) Ireland S.	25	10	46	57	34.5	166	(229)	288	274	[269]	293	305	276.3
C (5) England S.E.	7	8	29	26	17.5	178	234	277	295	295	305	301	284.5
D (4) Midlands	14	13	36	38	25.3	181	232	261	283	284	296	296	275.3
E (3) England E	13	9	30	19	17.7	183	240	274	294	294	289	292	280.5
F (7) England N.W.	16	16	28	34	23.5	179	232	263	277	273	287	292	270.7
G (9) Ireland N.	11	10	47	49	29.3	168	235	[258]	278	258	291	(293)	268.8
H (6) Scotland W.	...	22	[50]	...	...	182	(238)	...	273	...	...	...	...
I (2) England N.E.	24	24	39	40	31.7	180	236	268	282	277	292	290	274.2
J (1) Scotland E.	43	30	41	41	38.7	(177)	231	265	276	261	283	288	267.3
K (0) Scotland N.	[50]	36	48	52	46.5	(176)	[257]	[268]	[265]	[266]	[292]	[290]	273.0
Isle of Man	[2]	[2]	(25)	(33)	15.5	[173]	[226]	[245]	[307]	[290]	[292]	[290]	275.0
Total Records Used	143	257	180	157	...	116	107	49	234	135	66	76	...
Mean of All	21.8	17.0	37.9	39.7	29.1	177.1	235.5	270.4	281.0	277.2	291.8	294.5	275.1
Month and Day	J. 22	J.17	F.7	F. 9	J. 29	Je. 26	Ag.23	S. 27	Oc. 8	Oc. 4	Oc.19	Oc. 21	Oc. 2
Average, 12 yrs., 1915-26	18.4	*23	41.2	41.9	31.2	170.0	230.4	271.2	*278	279.7	294.3	298.9	275.4
Month and Day	J.19	J.23	F.10	F.11	J.31	Je. 28	Ag.18	S.28	Oc. 5	Oc. 7	Oc.21	Oc. 26	Oc. 2

* Average for 35 years, 1891-1925.

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TABLE XIV.—Observations of Plants and Birds taken at Hevingham, Norfolk, 1926, by Major H. S. Marsham.

Plants. (First Flowering, Fl., or Leafing, L.)	Average. All Years.	Average. 35 Years, 1751-85.	Average. 35 Years, 1891-1925.	1926.	Difference from Average, 1891-1925.
*Snowdrop Fl. . . (147)	16	19	19	23	+ 4
Wood Anemone Fl. (122)	85	91	79	66	— 13
*Hawthorn Fl. . . (145)	132	131	132	115	— 17
Turnip Fl. . . . (119)	96	96	108	95	— 13
Hawthorn L. . . (153)	68	72	71	47	— 24
Sycamore L. . . (143)	93	90	90	63	— 27
*Birch L. . . . (143)	94	92	97	80	— 17
Elm (Common) L. (116)	95	90	102	69	— 33
Mountain Ash L. . (133)	96	96	96	73	— 23
*Oak L. . . . . (146)	115	118	110	94	— 16
*Beech L. . . . (146)	113	116	113	99	— 14
*Horse Chestnut L. (141)	94	96	96	80	— 16
Chestnut L. . . . (123)	110	115	109	83	— 26
Hornbeam L. . . (128)	97	103	101	94	— 7
Ash L. . . . . (126)	119	122	118	99	— 19
*Lime L. . . . . (135)	104	105	102	63	— 39
Maple L. . . . . (86)	107	110	107	94	— 13
Average of all 17 . .	96	100	97	79	— 18

Birds, &c. (First Appearance or Song).	Average. All Years.	Average. 35 Years, 1751-85.	Average. 35 Years, 1891-1925.	1926.	Difference from Average, 1891-1925.
Swallow . . . . (154)	100	105	113	103	— 10
Cuckoo . . . . (150)	115	115	113	105	— 8
Nightingale . . . (118)	116	117	118	...	...
Nightjar . . . . (68)	144	142	...	...	...
Thrush . . . . (132)	27	37	28	7	— 21
Ringdove ‡ . . . (104)	53	54	...	138	+[illegible]
Rooks Build . . (148)	61	64	62	52	— 10
Young Rooks . . (145)	102	102	104	104	0
Yellow Butterfly . (129)	78	71	91	55	— 36
Frogs Croak . . (144)	83	82	89	62	— 27
Average of all 10 . . .	80	80	91½	...	...
Comparison with the Society's Series.					
*Mean of 7 Plants . . .	95	97	96	70	— 26
Mean of Society's 7 Plants (Dist. E.). †	...	...	93	80	— 13
Swallow (Society's Mean in Dist. E)	...	...	100	103	+ 3
Cuckoo (Society's Mean in Dist. E)	...	...	111	105	— 6

* The seven plants used for comparison are marked *.

† The first seven plants, hazel to hawthorn, in the Society's list.

‡ Until 1915 this referred to *any* pigeon cooing, but is now strictly confined to the Turtle Dove. The average for the last 12 years is 127 (May 7).

The bracketed figures in the names column show the actual number of years observed since the record commenced in 1736.

Errata 1925 Report.

P. 299. Mean of District A for 1917, for "141" read "142."

P. 310. S. Birmingham, read as follows:—mean 114.5, Willow Warbler 101, Sand Martin 104, Tree Pipit 101, Yellow Wagtail 103.

P. 316. Trees generally in full leaf, read "May 8 (128)."

DISCUSSION.

Mr. L. C. W. Bonacina remarked that he could never hear the Annual Phenological Report read, or do any phenological observing himself, without feeling that the subject was in reality the most complex in meteorology. Physical relationship might be complicated, but when one got to biological reactions one never quite knew where one was in attempting to draw reliable generalisations. He therefore particularly welcomed what Mr. Clark had said about the co-operation of foreign countries. This would greatly assist our own valuable annual reports in elucidating bio-climatic relations as time went on.

The earliness of the spring "isakairs" in 1926 seemed specially remarkable in view of the great cold in November and December, 1925—a genuine "old-fashioned Christmas" at any rate in the North.

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Perhaps the warmth of the later winter months of 1925-26 coming after the frost had provoked a quicker reaction than if the early winter had been mild. All these factors had to be borne in mind in interpreting results. In this connection he thought that Mr. Clark's suggestion that the maple was an exceptionally sensitive indicator of *current* weather conditions should be followed up. It should, Mr. Bonacina thought, be remembered that phenological mean dates represented a stable adaptation to climate, and that force of habit must be a factor tending to minimise the effects of weather vicissitudes from year to year and keeping them within limits. In the bitter spring of 1917 vegetation rushed forth the moment the restraint of frost and snow was removed.

In regard to Mr. Clark's remarks about the erratic behaviour of migrants, Mr. Bonacina said that it was known that the determining factor in bird-migration was the strength of the sunlight, not the temperature. One saw this very clearly, too, in the fact that most of our English summer migrants arrived in April and began to leave in August, showing parallelisms with the seasonal curve of sunlight rather than of temperature.

Finally, Mr. Clark had referred to the valuable co-operation of Marlborough College, and he (Mr. Bonacina) would like to suggest that Felstead School, in Essex, which had great natural history traditions, might be approached with advantage.

The PRESIDENT (Sir Gilbert Walker) expressed the thanks of the Society to the Phenological Committee for the very great labour they had expended in the preparation of the report.

Ground Day Visibility at Cranwell, Lincs., in Relation to the Type of Air.[1]

This note endeavours to determine what relationship, if any, exists between the type of air and the horizontal visibility observed at Cranwell. The visibility at 13h. was chosen so that the occurrence of morning and evening mist or fog did not enter into consideration. The type of air over Cranwell each day was determined by a day-to-day examination of the *Daily Weather Reports* of the Meteorological Office, London. For each day the air was classified under one of the five following heads :— Polar, old polar, equatorial, old equatorial, doubtful. Polar air was defined as air flowing directly from polar regions southwards to the British Isles with only slight deviations from the north-south pole. Old polar air was defined as air of polar origin but which has reached the British Isles after very considerable deviations from a direct path. Equatorial and old equatorial were defined in a corresponding manner. Visibility (13h.) was classified under three heads :—Good or very good (13 miles or more), indifferent or fair ($2\frac{1}{4}$ to 13 miles), and bad or poor (less than $2\frac{1}{4}$ miles). Further, the year was divided into two seasons, winter, Oct.-Mar., and summer, Apr.-Sept.

In both seasons polar air gives the highest percentage of good visibility, but on the other hand it is responsible for the largest percentage of poor or bad visibilities. Equatorial air in summer gives a very low percentage of good visibilities; a high percentage of indifferent visibilities and a low percentage of bad.

[1] From a paper by Messrs. W. H. Pick and J. S. Farquharson. The manuscript is preserved in the Society's Library.

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Considering the change in visibility which occurs with a change in the type of air, one or two rather surprising facts emerge. For a change from polar to equatorial air, out of a total of 212 cases during seven years 90 give an improvement in visibility and 70 cases show a deterioration, while for a change from equatorial to polar of 208 cases, 80 give an improvement and 85 a deterioration.

Abstract.

A Spanish Meteorological Society.

The formation of a new society for the furtherance of the study of meteorology is an event of no small moment in the history of the science, and it is with real pleasure that we learn of the constitution of the "Sociedad Española de Meteorologia." The inauguration meeting was held on February 5th, 1927, and under the presidency of Dr. E. Meseguer, the Director of the Spanish Meteorological Service, the headquarters of the society were established at Apartado 285, Madrid.

The first number of the proceedings of the new society, "Anales de la Sociedad Española de Meteorologia," contains a series of papers which will appeal to a wide circle of readers.

The first of these on orographic rainfall by Sr. M. Doporto is a mathematical treatment of the effect of orographic features on rainfall measurements. The area dealt with is that mountainous region, the Sierra de Grazalema, lying in the south of Spain between Cadiz and Malaga. The rainfall due to land contours is obtained by subtracting from the actual measurements obtained, the rainfall measured at or near sea level. The sea level station chosen is Puerto de Santa Maria. Assuming that the connecting equation is of the form

$$G' = W_0 q e^x$$

where G' is the orographic rainfall, W_0 that at sea level, q a constant for the station and x the height above sea level, the solution is simplified by substituting for the actual curve of contours a series of straight line equations and integrating step by step. The final results obtained along the line Sanlúcar to Malaga are given graphically, together with the curve of the profile of the section, the two, on arbitrary scales, showing great similarity.

Sr. F. Fariña examines statistically the relation of night minima at Madrid to the temperature of the wet bulb read on the previous evening—an investigation conducted on very much the same lines as has already been done in America (*M.W. Review*, August, 1917, and *Supplement* 16).

The close relationship which is growing up between meteorology and aviation is reflected in a useful summary by Dr. E. Meseguer, of the weather on the Guinea air routes, together with particulars of the way in which current weather information can be obtained for any particular section or sections of the route followed.

There follows a theoretical examination of the conception of temperature in matter and in radiation by Sr. A. Vallesa.

The President, Dr. Meseguer, at the same time appeals for both material support and scientific collaboration—an appeal which we feel sure will meet with a ready response from English readers.

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METEOROLOGICAL STUDIES IN CONNECTION WITH THE TORONTO MEETING OF THE BRITISH ASSOCIATION.

PART I.—INTRODUCTION.

The meeting of the British Association at Toronto in 1924 was attended by several meteorologists, some of whom made the outward voyage together in the ss. *Caronia*. Some of them returned in company on the ss. *Lancastria*.

To make arrangements for such meteorological work as might be profitable on the voyages, a small committee was appointed by the Royal Meteorological Society.

On the outward voyage facilities for the work were kindly given by Captain E. G. Diggle. During the voyages daily weather maps were prepared by Messrs. J. Bjerknes and M. A. Giblett from data received by wireless telegraphy. It was found possible in mid-ocean to draw a weather chart extending from Russia across the Atlantic to the Pacific coast of America, but during the later stages of the voyage less complete information was available. Forecasts based on the charts were posted regularly in the ship.

For use on the voyage a sensitive electrical thermometer which could be raised to various heights above the deck had been constructed by Mr. L. F. Richardson. Frequent observations were made with this apparatus under various conditions. Mr. Richardson's account of this investigation is printed below. A series of temperature observations was made on the bridge of the *Caronia* during the voyage. Mr. Whipple contributes to this report a short discussion of the observations.

Mr. Richardson's apparatus was utilised again in the ss. *Lancastria* on the return voyage and valuable results were obtained. The meteorological conditions at that time were of special interest. The passage of a deep cyclone which raced the ship across the Atlantic was anxiously watched by all on board. The preparation of the detailed account of the voyage has been unavoidably delayed. It is hoped that it will be ready for publication shortly.

PART II.

THE VARIATION OF TEMPERATURE WITH HEIGHT IN THE FIRST 44 METRES ABOVE THE NORTH ATLANTIC.

[Read at the British Association, Toronto, 1924.]

Many records of vertical variation of temperature over the sea have been published, for example, a long series in the Adriatic near Pola ("Beobachtungen mit bemannten, unbemannten . . . u.s.w. herausgegeben von Hergesell, Lindenberg"; a series near Crinan, Scotland, by W. H. Dines; over the Newfoundland banks, by G. I. Taylor; Scotia Report, H.M. Stationery Office, 1913; and a collection for the North Atlantic Trade-Wind, discussed by Sverdrup (Leipzig Geophys. Institute). However, all these, as far as we know, relate mainly to heights above masthead and do not give detail near the sea.[1]

[1] Since this was written N. K. Johnson has observed close to the sea. *Q.J.R. Meteor. Soc.*, Jan., 1927.

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Preliminary arrangements for a brief study of this subject were made in 1924 by a Committee of the Royal Meteorological Society, consisting of E. Gold, L. G. Garbett, M. A. Giblett, L. F. Richardson, Sir Napier Shaw, G. I. Taylor and F. J. W. Whipple. The preparation of the apparatus was entrusted to L. F. Richardson. On board ss. *Caronia*, with the permission of Captain E. G. Diggle and the active support of Chief Officer J. G. Bisset, a number of observations were obtained by co-operation between M. A. Giblett, R. W. Paul, L. F. Richardson, J. J. Shaw, E. A. Watson, F. J. W. Whipple, R. S. Whipple and other members of the British Association party. This was in July and August, 1924, between Liverpool and the St. Lawrence river.

The Thermometer and Screens.

The chief difficulties in the way of accurate measurement of temperature are rain, radiation, heating of the thermometer by friction, or by adiabatic compression and the rapid alternation of hot and cold patches in the atmosphere. Leaving aside this last, which is natural and inevitable, the other difficulties were met in the following way:—The screen consisted of an aluminium pipe 40 cm. long, 10 cm. in diameter; inside this a smaller aluminium pipe, 28 cm. long and 6 cm. in diameter, was held co-axially in position by three non-conducting strings of catgut. Within the inner pipe was placed the resistance thermometer, which was made of a kind of cloth specially woven with silk ribbon as warp and silk insulated wire as weft. The piece of cloth was bent to form a pipe 15 cm. long and 4 cm. diameter which was fixed co-axially with the others. A tail fin 22 cm. square on the outer pipe tended to swivel the screen parallel to the wind. In this way the air passed freely over the thermometer without much friction or change of density, while radiation could only enter as a narrow bundle impinging at a glancing angle on the thermometric cloth. The automatic exclusion of driving rain presents with this apparatus an unsolved problem.[2] By personal attention it might be possible to tilt the screen so as to keep its axis normal to the path of the drops. However, this was not attempted and the two observations made in drizzle and shown by dotted lines in Fig. 1 are suspect.

Incidentally, we tested the effect of nearly closing the rear end of the screen while the front end pointed to meet an air current advancing at about 10 metres a second relative to the instrument. The readings were:—Rear nearly closed 282.1°A.; rear end open as usual 281.8°A. Of this change the adiabatic compression due to the pitot tube effect would account for only 0.05°C.

The Electrical Measurements.

The success of the whole scheme depended on having a galvanometer sensitive to 2 micro-ampères and undisturbed by the motion of the ship. Such an instrument, known as the "small string galvanometer" was kindly lent by the Cambridge Instrument Co., and proved very convenient. Its resistance was 12 ohms.

[2] But see Johnson *loc. cit.*

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On land, a mirror-galvanometer works well with a thermocouple for measuring these small differences of temperature. At sea, the best available galvanometer is necessarily less sensitive and so a resistance thermometer must be used. The resistance in the screen consisted of about 66 ohms of No. 36 S.W.G. copper wire doubly covered with silk and then either shellaced or rubbered. It was found that 0.05 ampères maintained for some minutes warmed it by 0.8°C. in still air. When on the mast the current was only 0.022 ampère which we might therefore expect to warm the coil above its surrounding by $0.8 \times (0.022/0.05)^2 = 0°.15$C. in still air. Actually the ventilation was 10 metres per second at least, and the electric current only on for a second or two at a time, so that the heating error was quite negligible. The Wheatstone net employed was merely what one of us (L.F.R.) happened to possess, a variety of "shunt-bridge." It had been standardised by the National Physical Laboratory and could be read to 0°.02C.; but as the customary Callendar and Griffith slide wire[3] would probably have been much more convenient, further description will not be given. The leads were made of copper and had a resistance equal to 1/70 of that of the wire in the screen. For cheapness additional compensating leading wires were not used. As this omission is contrary to standard practice it needs to be justified by pointing out that the strong ventilation produced by the ship's motion combined with headwinds, together with the moderate radiation of skies mostly overcast or at night, made it unlikely that the leading wires should differ from the air temperature by as much as 3°.5C., and even in that event the measured temperature would be wrong by only 0°.05C., which is much less than the variations observed as set out in Fig. 1.

The instrument was calibrated by holding it close alongside an Assmann aspirated thermometer and taking simultaneous readings at three temperatures. All the mercury thermometers employed were compared in water and corrected accordingly. Several of them had N.P.L. certificates. When resistances were plotted against temperatures they lay on a straight line to within 0°.05c. As a check, it is well to note that this line corresponded to an increase of 0.00398 of the resistance at 18°C. per 1°C. rise of temperature. This is the temperature coefficient of a not quite pure copper.

The Variation with Height.

This was observed by hauling the resistance thermometer up and down and taking readings in rapid succession; usually two readings at the lower level were arranged alternately with three at the upper level, so that the mean time was nearly the same for both. The thermometer was always 2 to 5 metres to one side of the foremast, and so was not likely to get into the wake of air warmed thereby.

All heights were measured by a tape when in comparative calm. Afterwards a correction was applied for the raising of the thermometer by the wind bending its halyard.

[3] See Watson's Textbook of Practical Physics.

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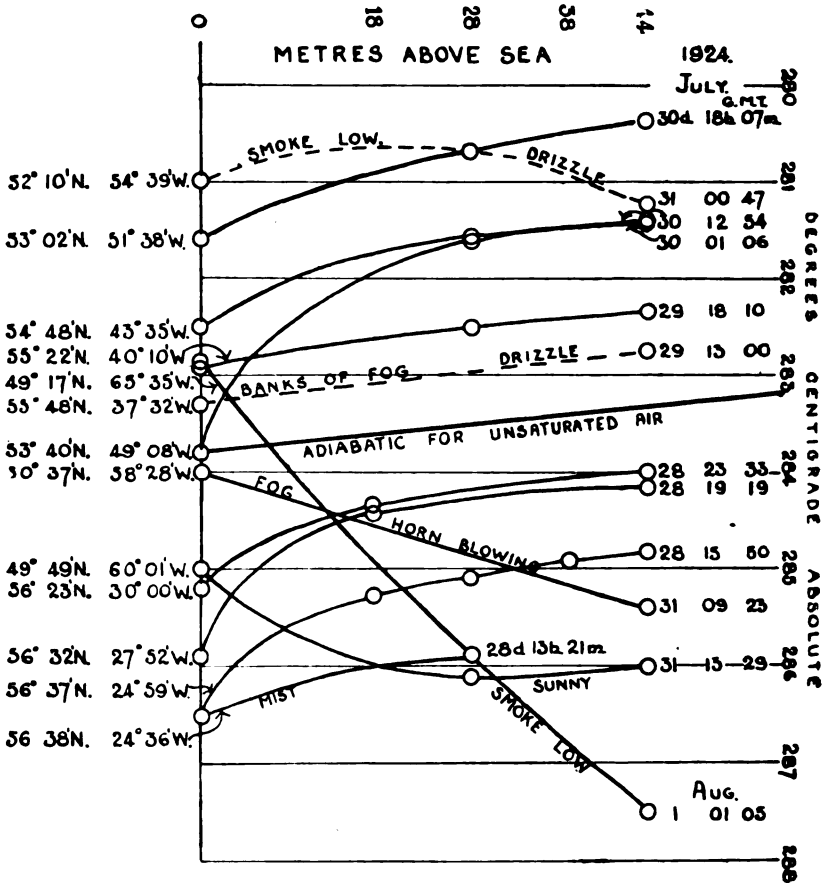

FIG. 1.—Air temperature over the sea.

The ploughing up of the air by the hull of the ship is a regrettable complication for which no correction has been found. The deck at the foremast was 20.0 metres[4] wide and 9.8 metres above the water close beside the ship. From the foremast to the bow was 37.7 metres.[4]

THE RESULTS.

In Fig. 1 the hollow dots represent fact, the curves connecting them are fiction. For comparison a straight line is added to show the adiabatic temperature-gradient for clear air. In order to lead the eye, the curves have been drawn as if the air gradually attained the temperature of the sea where they meet. But F. J. W. Whipple[5] and G. I. Taylor[6] have remarked that it would be more correct to draw the graph as a straight line passing through the observed points at 28 and 44 metres and making, close to the

[4] Data kindly supplied by the Cunard Co.
[5] Toronto discussion at British Association.
[6] Private communication.

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water surface, a sharp bend towards the temperature of the sea. See also the observations by N. K. Johnson[7] which do show some gradual curving. Our Fig. 1 shows that:—

(1) The labile adiabatic temperature-gradient was the prevailing one between 26 and 44 metres above the sea.

(2) But that between the sea and a level 26 metres above it the most various up-gradients of temperature occurred. This layer was often exceedingly unstable and at other times very stable.

(3) On two occasions the electric thermometer showed that the air was warmer at 44 m. than at 26 m., once 50 km. W.N.W. of Belle Isle, and most markedly about 3 km. from the south shore of the St. Lawrence. In both instances the inversion was over a patch of cold water lying within 100 km. of water or land decidedly warmer, so that it seems fair to explain the inversion of temperature by a shift of the air relative to its substratum.

On another occasion between Newfoundland and Labrador the air at 44 m. was warmer than the sea, and the ship's fog-horn was blowing.

Part III.

Assmann Aspirated Thermometer Readings.

A large number of readings of the Assmann aspirated thermometers were made in different positions on the bridge of the *Caronia*, the object being to ascertain by how much the temperatures recorded by the thermometer in the ship's screen deviated from the temperature of the free atmosphere at the same height above the sea. The screen was the one supplied by the Meteorological Office for the routine observations; it was fixed on the port side of the bridge house and therefore exposed to direct sunshine on this voyage.

Assmann readings were made to determine (1) the temperature of air which could not have come in contact with any part of the ship; (2) the temperature of air behind the weather board on the bridge; (3) the temperature of air close to the ship's screen. The difference between the readings of the first two groups was consistently high. With the sky overcast it was about 2°F., in sunshine about 3°F. On the only occasion when readings were made at night the difference was reduced to 0°.6F. (overcast sky, head wind, Force 3). The air behind the windscreen is obviously in an eddy; it is blowing upwards from the deck of the bridge and it has been in more or less intimate contact with this deck and with the bulwarks. On one occasion the temperature of these objects was ascertained approximately by stroking them with a thermometer bulb. They were found to be 8°F. above free-air temperature. Contact with them raised the temperature of the eddying air by 2°F.

The difference between the readings of the second and third groups mentioned above was insignificant, generally a few tenths of a degree, *i.e.*, the air close to the ship's screen was at the same temperature as that in other parts of the eddy behind the protecting windscreen. (There was no evidence that the heat from

[7] *loc cit.*

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the funnel affected the matter; it might have done so with a following wind.) Finally it was found that the temperature recorded inside the screen agreed with this eddy temperature when the sky was overcast, but with bright sunshine the reading in the screen was the higher by a degree or more.

The greatest difference between the temperature in the screen and in the free atmosphere was found on the St. Lawrence, where it amounted to 5°F. Experiment showed that in such circumstances the true temperature could be found by holding up an ordinary thermometer in front of the bridge, the only precaution necessary being to shield the bulb from direct sunshine.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 16, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

JOHN OLIVER AUGUSTUS ARKELL, Goodrington, Swindon, Wilts.

Mrs. MARIANNE BATHURST BAIRD FERGUSON, Rebeg Lodge, Kirkhill, Inverness-shire.

JAMES VERNON KEEGAN, 32, Fenchurch Street, E.C.3.

FRED E. LUPTON, East Cottage, Lemmington, Alnwick, Northumberland.

Rev. EUSTACE MALDEN, Henley House, Frant, Tunbridge Wells.

The Hon. ANNA JANE PECKOVER, Bank House, Wisbech, Cambs., and

Rev. CHARLES HAMPDEN BASIL WOODD, M.A., Pleshey, near Chelmsford, Essex.

April 20, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society:—

RAYMOND GIFFORD BURDER, Field House, Loughborough, Leics., and

WILLIAM BURGESS HAINES, D.Sc., F.Inst.P., D.I.C., The Rubber Research Institute of Malaya, Kuala Lumpur, F.M.S.

At this meeting the first Report of the Atmospherics and Weather Committee, entitled "The Range of Atmospherics," was brought forward by Mr. R. A. Watson Watt, Secretary to the Committee. The Report will be published as a Supplement to the *Quarterly Journal*.

April 28, 1927.

At this meeting the Rt. Hon. Sir SAMUEL HOARE, Bart., C.M.G., M.P., Secretary of State for Air, addressed the Society on the subject of his recent flight to the East (see p. 233).

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CORRESPONDENCE AND NOTES.

Weather Observations at Wrentham, Suffolk, 1673 and 1674. By Ivan D. Margary, M.A.

The Society has been fortunate in obtaining a copy of a very interesting old weather record kept at Wrentham, near Lowestoft, in 1673-74. It forms part of an extensive general diary kept by Sir Philip Skippon during the period 1667-1677. The original diary (a small leather-bound book of 143 folios) is in the collection of Capt. the Hon. Michael Knatchbull, Mersham-le-Hatch, Kent, who has very kindly allowed the records to be published. The Society is also greatly indebted to Mrs. Ivo Hood, Hon. Editorial Secretary of the Norfolk and Norwich Archæological Society, for furnishing a complete copy of the meteorological observations which was forwarded to the Society by Mr. A. W. Preston, F.R.Met.Soc.

Sir Philip Skippon was the son of the well-known Parliamentarian, General Philip Skippon, and came of a very old Norfolk family known locally as far back as 1298. He has been described as a scientific man and traveller, and his education is shown by the unusually good spelling and neat writing of the diary. The Skippon estates were at Foulsham in Norfolk, but the diarist lived chiefly at his wife's home in Wrentham, where the weather observations were made.

The diary is extraordinarily interesting, containing notes on all sorts of subjects, from descriptions of agricultural methods, local phrases and sayings, and various country observations made during Skippon's frequent journeys, to events of national interest such as the building of the London Fire Monument, a view of the model of the new St. Paul's, and mention of numerous sea-fights off the East Anglian coast, including an eye-witness account of the Battle of Sole (Southwold) Bay, 1672. For further details of the diary's general notes the reader is referred to the paper by Mrs. Hood[1] in which the interesting parts of the diary are fully given, together with a much more complete account of the Skippon family. The present writer has found the paper most useful in preparing this summary.

Skippon does not quote many weather sayings, but the following may be worth mentioning:—

> "Some Countrymen observe yt it usually proves a wett Summer if Crowes and magpyes etc. build their nests on ye highest tops of trees; and when they build on ye lower branches the summer proves dry."
>
> "Some also sow their Summer Corne soon when the Rosemary flowers come out of ye tops of ye plants and sow late if ye flowers come out in lower branches."

Some interesting weather notes are given in the earlier years before the systematic records begin. (For the purpose of modern comparisons all dates mentioned here have been corrected to the present calendar by adding ten days.) On Dec. 28, 1668, Skippon was "much hindered by floods at Chelmsford and Colchester," while travelling from London. On April 3, 1669, he records "a foot of snow at Wrentham." On Feb. 27, 1670, he notes "This winter had 2 snowes that lay a good while on the ground. . . . The liquor in my Roman Weather glasse at ye coldest sunke to 11 and 12." On April 2, 1671, "the Tortoise came out of the ground."

[1] Christobel M. Hood. "An East Anglian Contemporary of Pepys," *Norfolk Archæology*, Vol. XXII., part II., 1925, p. 147.

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He describes an inundation of the marshes near Lynn :—

"Marshland by a storme Munday Sept. 1671 was allmost quite drownd, etc.; many cattle lost, ye bankes broken downe and in many places being too low overflowne. Whilst we were there ye Spring tides came over of Mershland, £8,000 damage there."

At the end of Feb. 1672 he describes the winter as very cold and severe, "in my Roman Weather glasse ye liquor at ye coldest this winter fell to 12." On Jan. 8, 1673, "happened that thunder and lightning in Garnsey which fired ye Powder and blew up ye castle where severall persons were killed; and ye same day Benenden church and 5 houses there, in Kent were burnt by that lightning. In Suffolk I observed no such thunder and lightning at that time." "The first week in January 1672/3 there were great rains and terrible sore winds which distressed 100 Colliers ships that were returning from Newcastle, severall of them were blown to ye Holland shore, one was sunk at Covehithe and others perished about Winterton."

These storms seem to have fired Skippon to take the regular observations, for these commenced in January 1673 and continued with some breaks until November 1674. The records consist of daily observations of wind direction, thermometer and barometer, with a description of the day's weather. Details of the time of observation and the nature of the instruments and their exposure are quite unknown, but the temperature frequently changes very little from day to day and it therefore seems likely that the thermometer was exposed indoors, most probably attached to the barometer. The daily readings are set out in Table I., and it will be seen that on some days three or even four readings were taken. In the case of the thermometer the second reading is always higher, which suggests that the usual observation hour was in the morning, possibly at noon or perhaps much earlier. Where two wind and three barometer observations are given, it is of course uncertain to which barometer reading the second wind record refers (if indeed they correspond at all), and they are simply given in the observer's order. The daily weather descriptions have been summarised by months and are given below.

February 1673. A cold and mainly fine month of the usual winter anticyclonic type. Snow on the 1st, 2nd, 3rd, then fine and frosty till the 17th. Rain on the 18th. Pressure fell rapidly on the 20th with snow, and an unsettled spell set in with further snow on the 22nd and 24th ("much snow in the afternoon") and alternating rainy and fair periods.

March. A stormy and rather cold month with much low pressure. Snow on the 13th, 14th, 15th ("much snow"), and low temperatures continued till the 23rd, when "pleasant spring weather" set in for the rest of the month. The 29th was "Overcast in ye forenane, after dinner a great storme of haile as big as large pistol bulletts and great thunder-claps."

April. Cold and stormy till the 18th, then fine and warmer. Low pressure continued with rainy periods, and snowstorms on the 7th, 8th, 9th. On the 14th and 16th "very rainy." Pressure rose on the 24th giving a short warm spell, but the 29th was rainy again.

May. A mainly fair and pleasant month, with a cool unsettled spell from the 15th to 29th. "Thick fogs" occurred on the 12th, 13th, 14th, with warm weather. Heavy rain fell on the 22nd and 23rd; 22nd, "Rain all ye afternoon and ye night following," 23rd, "rain and cold weather, grounds overflowed," 24th, "Overcast and sometimes rain. Cold. Sun did not shine these 3 last dayes."

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TABLE I.—Daily Observations at Wrentham, Suffolk, by Sir Philip Skippon.

(The dates have been corrected by + 10 days to correspond with the modern calendar.)

Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer
1673.				Mar.				Apr.				May.			
Jan.				1	W	2½	28⅜	9	SW	2	29⅛	15	W	5	29½
27	N	2	29¾	2	E	2½	29				29		NW		
28	N	2¼	29½				29⅛	10	NW	2	28⅝	16	NW	4½	29⅛
...	...	...	...	2	—	2½	29		N			17	NE	4½	29⅛
31	E	2½	29½				28⅞	11	N	2	29	18	NE	4½	29⅛
Feb.							28⅝				29⅛		N		
1	N	2	29⅝				28⅝	12	N	2	29¼	19	NE	4	29⅛
2	NE	1½	29⅜	...	...	...	...		NW		29⅛		N		
			29⅞	11	NW	4	29	13	SE	2	29⅛	20	NE	4½	29⅝
3	NE	1¼	30				29⅛		E		29	21	NE	4	29⅝
4	E	0⅞	30⅛	12	NW	2½	29⅜	14	N	2	29				29½
5	E	1	30	13	NW	1½	29⅜	15	E	2	29⅛	22	N	4	29½
6	E	1	29⅞	14	NW	1½	29⅜	16	N	2	29¼	23	N	4	29⅜
			29¾	15	NE	1½	29⅛				29				29¼
7	ESE	1¼	29¾	16	NE	2	29⅜	17	E	2	29	24	NE	5	29¼
			29⅝				29½	18	E	2½	29⅛	25	E	6	29⅜
8	E	1⅜	29⅝	17	NE	2	29⅝		SE				NE		
9	N	1⅝	29⅝	18	W	2½	29½	19	SE	3	29	26	N	5½	29⅜
			29¾	19	SE	2	29⅜	20	SE	3	29⅛	27	N	5	29½
10	N	1½	29⅞				29¼		S ; E			28	N	4½	29½
	SW		29¾	20	S	2½	29⅛	21	E	4	29½	29	NE	5	29⅝
11	SW	1¾	29⅝				29¼	22	SE	4	29⅛	30	SE	5	29⅜
12	SW	1⅜	29⅝	21	NW	2	29½	23	NE	4½	29⅛		E		
			29¾	22	E	1	29⅜	24	NE	4	29⅝	31	S	6	29¼
13	NE	1½	29⅞		SE		29¼	25	N	3½	29¾		SE ; S		
14	NE	1¾	30	23	SES	2	29⅛	26	NE	4½	29⅝	June.			
15	NE	1¾	29⅞				29	27	SE	5	29½	1	SW	6½	29⅝
16	NE	1¾	29⅞	24	SE	2½	29⅛	28	SE	5½	29¼	2	SE	6	29½
17	E	1¾	29⅞	25	SES	3	29¼		S		29	3	SW	6	29
	SE ; E			26	S	3½	29⅜	29	S	5	29	4	SW	6	29⅛
18	SE	1½	29¾				29	30	SW	4	29⅛		S ; SW		
19	NE	1¾	29⅞	27	S	3½	29⅛	May.				5	SW	6	29¼
20	NE	1¾	29⅞		SW		29	1	SW	4	29¼		S ; SE		
			29¾	28	W	4	29½	2	SE	4	29¼	6	SW	6½	29⅜
21	SW	1¾	29½				29⅜		W				N ; W		
			29⅜	29	WSW	4	29⅜	3	SW	5	29⅜	7	W	5½	29⅝
			29	30	SE	4	29½		E				NW	7	29¼
22	NW	2¼	29⅛		E			4	E	5	29½		NE		
			29¼	31	N	3¾	29⅝	5	SE	5	29¼	8	SW	5½	29⅜
23	N	1⅛	29¼	Apr.					S		29⅛			7	29¼
			29⅜	1	NE	3½	29½	6	S	5½	29¼	9	SW	6	29⅜
24	SE	1⅛	29¼	2	E	2½	29⅜	7	NW	5	29¼	10	SW	6½	29⅜
			28⅞	3	SE	2½	29¼	8	SE	4	29½		SE		
25	SES	1½	28¾				29⅛	9	SE	5	29½	11	NE	7	29⅜
			28⅜	4	S	3	28¾		E			12	—	6½	29⅜
26	S	2½	28½		SE		28¾	10	NE	5	29¼	...	...	...	...
			28⅛		S			11	NE	5½	29⅛	July.			
27	SE	3	28⅜	5	SE	3	28⅞	12	N	5½	29⅛	2	S	6½	29⅛
	SW	2⅞	28¼	6	NE	3	29	13	N	5½	29⅛	3	SW	6½	29¼
			28⅝	7	N	3	29⅜			6½	29¼	4	SW	6	29½
28	E	2¼	28⅞	8	N	2½	29⅜	14	NW	5½	29⅜		NW		
					NW		29½						SW		

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TABLE I.—Daily Observations at Wrentham, Suffolk, by Sir Philip Skipton. —*continued.*

Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer
July.				Aug.				Sept.				Oct.			
5	SWS	5½	29½	21	SW	6	29⅛	30	SW	4½	28⅞	31	W	3	29⅛
	S		29⅜				29	Oct.							29⅛
6	S	6	29⅛	22	S	7	29⅛	1	NW	5	28¼	Nov.			
7	SW	7	29⅞		SW						28¾	1	SW	3½	29⅛
8	S	6½	29⅛	23	SW	7	29¼				28⅞	2	W	4	29⅛
9	W ; S	6½	29¼		E ; NE			2	SW	3½	29¼	3	SW	4	29⅛
10	SW	6½	29⅜	24	S	7	29¼				29	4	SW	4½	29⅛
...	...	...	...	25	S	7	29¼				28⅞	5	SW	4½	29⅛
15	S	7	29⅜		NW						28¾	6	SW	4½	29⅛
16	S	6½	29⅜	26	NW	7	29¼	3	SSW	4	28¾	7	W	4½	29⅛
	SW			27	W	6½	29⅜	4	S; W	4½	29	8	S	4½	29⅛
17	S	6½	29⅜	28	W	6½	29⅜	5	NW	3½	29⅛		NE		
	SW		29⅛	29	SW	6½	29⅜		W;SW		29¾	9	NE	3½	29⅛
18	S ; SE	6½	29¼				29¼	6	S	3½	29⅝	10	NE	3	29⅛
	NE ; S			30	SW	6½	29⅛		SW		29½	11	E	3½	29⅛
19	SE	6½	29¼		W			7	SW	4	29⅜	12	NE	3½	29⅛
	SW		28⅞	31	SW	5½	29⅛				29½	13	NE	3	29⅛
20	SW	6½	29¼		W		29	8	W	4½	29⅛	...	...	...	...
21	S	6½	29½	Sept.				9	SW	4½	29½	Dec.			
22	S	7	29¼	1	SE	5½	29⅜	10	SW	4	29	31	W	3	29
23	SE	7	29¼	2	SE	5½	29⅜				29⅛	1674.			
			29⅛	3	S	7	29⅛	11	SW	4	29⅜	Jan.			
24	SE	7	29	4	SE	7	29⅜	12	SW	4	29⅜	1	W	3	29⅛
25	N	7	29⅛	5	SW	7	29⅛	13	SW	4	29⅜	2	S	3½	29⅛
26	N	7	29¼	6	S	6	29¼				29¼	3	S	3½	29⅛
	SE			7	SW	5½	29¼				29	4	W	3½	29⅛
27	S ; W	7½	29¼	8	SW	5½	29¼	14	NW	4	29⅛	5	SW	3½	29⅜
28	S	8	29¼	9	SW	6	29¼	15	W	3	29¼	6	S	3½	29⅜
29	S	7½	29⅜	10	SW	6	29	16	SW	3	28⅞	7	S	3½	29
30	E	8	29⅜	11	SW	6	29⅞	17	NW	3	29	8	S	3½	29
31	S ; W	7½	29¼	12	NE	6	29	18	NW	3	29¼	9	SW	3	29⅛
Aug.							29⅞	19	SW	2½	29½	10	SE	2	29⅛
1	SW	7½	29½	13	NW	5	29	20	S	3	29⅜		S		28⅞
2	SW	7½	29⅜		W			21	SE	4	29⅛	11	SW	2½	28⅞
3	W	8	29¼	14	W	4½	29¼				29	12	W	2	29⅛
4	W	7½	29⅛	15	SW	5	29⅛				28¾				29⅛
5	SW	7	29¼	16	SW	5½	29⅛	22	SE	4	29⅞	13	W	2½	29⅛
6	S	7½	29⅛	17	SW	5½	29¼				29¼	14	W	2½	29⅛
7	SE	8	29¼				29⅜	23	SW	3½	28¾	15	SW	2	29⅛
	SW			18	SW	5½	29¼				29	16	S	1½	29⅛
8	—	6½	29⅛	19	SW	5½	29⅜				29⅛		SE		
9	SW	6½	29¼	20	SW	5½	29¼	24	SE	3¼	29¼	17	E	1½	29⅛
10	SW	6½	29⅛	21	SW	5½	29⅛				29	18	SE	2	29⅜
11	SW	6½	29				29				29⅞	19	S	2½	29⅛
12	SW	6½	29½	22	SW	6½	29⅛	25	S	3½	28⅝	20	SW	2½	29
13	S	6½	29	23	W	6	29⅜				29	21	SE	2½	28⅞
14	SW	6½	29¼	24	SW	5½	29⅜	26	SW	4	29¼	22	S	2½	28⅞
15	SW	6½	29¼	25	W	5	29⅝	27	S	4	29⅛	23	SW	2½	29⅛
16	W	6½	29⅛	26	SW	5	29⅜				29½	24	SW	3	29⅝
17	NWN	6½	29⅜	27	SW	5	28⅝	28	S	4	29⅛	25	NW	3	29⅛
18	N	6	29½				28⅞	29	NW	4	29½		NE		
19	NW	6	29⅜	28	SW	5	28⅞				29¾	26	W	3	28⅝
20	NE	6	29¼	29	SW	5	28¾	30	SW	3	29⅞	27	N	2½	29⅛
	SE										29¾				

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TABLE I.—Daily Observations at Wrentham, Suffolk, by Sir Philip Skippon. —*continued.*

Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer
Jan.				Mar.				Apr.				June			
28	S	2	28¾	15	NE	0½	29⅛	22	SE	3½	29¼	18	W	6	29⅜
29	SW	2½	28⅝				29¼	23	SE	4	29¼	19	SW	6	29⅜
			28½	16	NE	0½	29⅛	24	NE	3½	29¼	20	SW	6½	29⅜
30	NW	2½	28¾				29¼	25	E ; N	3½	29⅛	21	SW	7	29⅜
31	NW	1½	29½	17	NE	0½	29⅜	26	SE	3½	29⅛	22	SE	6	29½
Feb.				18	NE	0½	29¼	27	NE	4	29¼	23	NW	7	29⅜
1	W	1	29¾				29⅛	28	NE	4	29¼	24	NW	6½	29⅜
2	SE	1	29¾	19	NE	0½	29	29	E	3½	29¼	25	W	6½	29½
3	S	1	29½		NW		29⅛	30	SE	3½	29	26	NW	6	29⅜
			29⅜				29¼	May				27	NW	6	29½
4	SE	1½	29½	20	W	1	29⅜	1	S	4	29	28	NW	5½	29½
5	E	2	29½	21	N	1	29½	...	...	...	...	29	NW	5½	29⅜
6	E	2	29½	22	N	1½	29⅜	3	S	4	29¼	30	NW	6	29⅜
7	E	2	29½	23	E	1½	29¼	4	W	4	29⅜	July			
8	SE	1½	29½		S		29	5	S	4	29⅜	1	NW	6	29½
9	S	2	29⅜	24	S	2	28⅞	6	S	4½	29⅜		SW		
10	SE	2	29				28¾	7	S	5	28⅞	2	SW	7	29⅜
11	SE	2½	29	25	SW	2½	28⅞	8	S	5	28⅞	3	NW	7	29⅜
12	SE	2	29	26	NE	3	28⅞	9	W	5	28⅞	4	NW	6	29⅜
13	NE	2	29¼	27	NE	2½	29	10	NW	5	29⅛	5	NW	6	29¼
14	NE	1	29⅛	28	NE	2	29	11	NW	4½	29	6	NW	6	29¼
15	NE	1	29⅜	29	NE	1½	29⅛	12	NW	4	29½	7	NW	5½	29⅜
16	NW	0½	29¼		NW		29¼	13	SE	3½	29¼	8	NW	5½	29⅜
	W			30	NW	1	29¼				29	9	NW	5½	29⅜
17	NE	1	29½	31	NE	2	29⅜	14	W	4½	29⅝	10	SW	5½	29⅜
18	E	1	29⅜				29½		NE			11	SW	6	29¼
19	NW	1	29¾	Apr.				15	SE	4½	29¼		S		29
20	SW	1	29¾	1	NE	2	29½	16	SE	5	29⅜	12	S ; N	6½	28⅞
21	NW	1	29½		NW			17	SE	5	29½	13	NW	5½	29
22	E	1	29¾	2	NW	2½	29⅜	18	SE	5	29¼		NE		
23	SE	1	29¼	3	NW	3	29⅜		E			14	W	5½	29
24	SE	1½	29		S			19	SE	5½	29⅜	15	SW	6	28¾
25	S	2	29⅜	4	SW	3	29⅜	20	SE	5	29¼				29⅜
			29	5	W	3	29⅜	21	E	5	29⅜	16	SW	5½	29¼
26	W	2	29⅛	6	W	3	29⅜	...	...	...	...	17	SW	5½	29⅞
27	SW	1½	29¼	7	SE	3½	29⅜	31	S	5½	29⅜	18	—	5½	29
28	N	2	29⅜	8	SE	3½	29⅝	June				19	SW	6	29
Mar.				9	NE	4	29⅜	1	SE	5½	29⅜	20	S	6	29¼
1	N	1	29⅜				29¼	2	SE	5½	29⅜	21	S	6	29¼
2	E	1½	29⅜	10	N	3	29¾	3	SE	6	29⅜	22	SW	6	29½
3	E	1½	29¼	11	N	3	29⅜	4	SW	6	29⅜	23	SW	6½	29
4	NE	2	29¼	12	E	3	29⅜	5	SW	6	29⅜	24	SW	6	29
5	SW	2	29				29¼	6	NW	6½	29⅝	25	S	6	29¼
			28¾	13	S	3	29	7	NW	6½	29⅝	26	S	6	29⅜
6	NE	2	28⅝	14	SE	3	28⅞	8	NW	6½	29½	27	S	6½	29¼
7	E	1	29	15	SE	3	28⅞	9	N	6	29¾	28	SE	7½	29¼
8	E	1	29⅛	16	SE	3	29	10	N	5½	29⅞	29	SW	7	29
9	NE	1½	29⅛	17	E	3½	29⅛	11	NW	5	29⅞	30	SE	7	29¼
10	NE	1½	29¼		SE			12	NW	5	29¾	31	SE	7	29⅜
11	NE	1	29¼	18	SE	3½	29¼	13	NE	5	29¼	Aug.			
12	NE	1	29⅜				29⅜	14	SE	5½	29½	1	S W	6½	29⅛
13	NE	1	29⅜	19	SE	3	29¾	15	S W	5½	29½				29
14	NE	1	29¼	20	W ; S	3	29⅜	16	SW	6	29½				28⅞
			29⅛	21	S	3	29½	17	NW	6	29⅜	2	SW	7	29½

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TABLE I.—Daily Observations at Wrentham, Suffolk, by Sir Philip Skippon. —*continued.*

Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer	Date	Wind	Thermometer	Barometer
Aug.				Aug.				Sept.				Oct.			
3	SW	7	29¼	25	NE	7	29¼	24	SW	4	29½	21	SE	4	29½
4	S	6½	29⅜	26	NW	7	29	25	SW	4½	29¼	22	SE	4	29½
5	S	7	29¼	...	...	...	...	26	NE	4½	29⅜	23	S	4	29¼
6	S	8	29⅛	Sept.				27	NE	4½	29⅛	...	...	...	...
7	S	7½	29⅛	5	NE	6	29	28	NE	4½	29⅜	28	SW	5	29½
8	S	7	29¼	6	NE	6½	29	29	NE	4	29⅜	29	SW	5	29½
9	S	6½	29¼	7	NE	6½	29⅛	30	NE	4	29⅜		S		
10	S	6½	29	8	SE	6	29⅛	Oct.				30	S	5	29½
11	SW	6	29¼	9	SW	6	29⅛	1	SW	4	29⅜	31	S	4	29⅝
12	SW	6	29⅛	10	W	6	29¼	2	SW	4	29	Nov.			
13	SW	6	29¼	11	NE	6	29⅝	3	NW	4½	29⅞	1	S	4	29½
14	SW	6	29		NW			4	NW	4	29⅞	2	S	4½	29
	NW			12	NE	6	29½	5	NW	4	29	3	S	4½	29
15	W	5½	29¼	...	...	...	...	6	NW	4	29¼	4	S	4½	28⅞
16	W	5	29⅜	15	NE	6	29½	7	NE	4	29½	5	S	4	29
17	NE	5	29¼	16	NE	6	29½	8	SE	4	29¼	6	S	4½	29
18	NE	5	29⅜	17	NE	6	29⅝	9	SE	4	29¼				28⅞
19	N	5	29⅜	18	N	6	29⅝	...	...	...	...	7	S	4½	28⅞
20	NE	5	29½	19	N	6	29⅝	16	SE	4½	29¼		W		29⅛
21	NE	5	29⅜	20	NE	6	29⅝	17	SE	4½	29⅜	8	NW	4	29⅛
22	NE	5½	29⅜	21	SE	6	29⅜	18	SE	4½	29¼		SW		29½
23	NE	6	29½	22	NW	6	29¼	19	SE	4	29½	9	S	5	29
24	NE	6	29⅜	23	NW	5	29¼	20	SE	4	29⅛				

June (till 12th only). Showery and unsettled but warm. On the 5th "these showery dayes much raine fell."

July. Warm and showery till the 21st, then fine and hot with occasional thundery showers; on the 24th a great shower in ye evening, and on the 31st in ye evening thunder and a great shower."

August. Warm and mainly fine, but unsettled from the 5th to 13th with thunderstorms on the 7th and 8th. On the 30th "it rained a great deale as it did most part of the following night."

September. A very stormy and unsettled month with frequent heavy rainstorms and gales and fair periods. The chief gales occurred on the 21st and 27th ("a great storm of wind and much rain ye night before").

October. The stormy weather continued through October with frequent heavy rains. On the 3rd "about 4 in ye afternoon a very smart crack of thunder and large hailstones 3 miles to the southward." Gales occurred on the 1st, 2nd, 16th, 21st, 22nd and 25th.

November (till 14th only). A fine quiet misty month. Pressure was much higher and it was evidently a November of the cloudy anticyclonic type.

January 1674. The month was mild and unsettled till the 10th with rainy periods and low pressure. A fine frosty spell followed till the 18th, but the rest of the month was again very wet and stormy, with snow on the 27th and 31st.

February. The month was cold and rather unsettled. Snow fell on the 3rd and 6th and there was heavy rain on the 10th-12th followed by a spell of hard frost and clear weather with some snow-showers until the 24th, when rain set in again.

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March. This was a very severe month. Snowfall was recorded on 18 days with almost continuous frost, except about the 23rd-26th, which were milder. There was persistent E and NE wind, occurring on as many as 23 days. A special note says "This cold snowy season ye crows and magpies picked flesh off living cows' backs. Wheat bread, vinegar, etc., was frozen this cold season."

April. A fine, pleasant month with some night frosts. Rainy about the 13th to 15th, and thunder with rain on the 20th and 26th. Phenological notes:—Tortoise appeared, April 6th; swallows began to appear about April 15th.

May. A mainly fine and warm month, though unsettled from the 6th to the 13th, and a thunderstorm on the 16th.

June. A fine and dry month with occasional showers, but generally rather cool.

July. The fine weather continued till the 11th, but the rest of the month was very unsettled with frequent thunderstorms. Thunder or lightning were recorded on 10 days. The chief storms occurred on the 15th and 23rd, and on the 19th "very great rain till 9 in ye morning."

August. The month was unsettled till the 13th with much rain, but afterwards was fine and quiet. Thunderstorm on the 5th.

September. Unsettled with much rain, except for a fine spell from the 12th to 22nd. On the 5th "Overcast and a little rain and some thunder about 10 in ye morning. Great rain about 8 miles off at Weselton."

October. A fine month with a rainy spell from the 5th to 10th.

November (till 9th only). Rain set in on the 3rd and stormy weather followed. On the 6th "very great storme of wind all night."

The monthly means of the thermometer and barometer readings have been prepared and are given in Table II., together with the prevailing winds. Where several observations were made on one day the first has alone been included in the means. Less than three weeks' observations are available in June 1673, November 1673 and 1674, which has clearly made the November temperature means too high. A satisfactory solution of the unknown temperature scale is hindered by ignorance of the observation hour. The only known old temperature scale which

TABLE II.—Monthly Means of Observations at Wrentham.

Month.	1673.				1674.			
	Prevailing Winds	Temperature	Suggested Equivalent in ° F.	Pressure (uncorrected)	Prevailing Winds	Temperature	Suggested Equivalent in ° F.	Pressure (uncorrected)
January	...	...	...	...	S; SW	2.6	45	29.22
February	NE; E	1.6	41	29.60	SE; E	1.5	40	29.30
March	SE; NW	2.6	45	29.27	NE; E	1.4	40	29.22
April	SE; N	3.1	49	29.19	SE	3.2	49	29.34
May	N; NE	4.9	58	29.40	S; SE	4.6	55	29.21
June	SW	6.2	65	29.23	NW; SW	5.9	63	29.54
July	S; SW	6.8	68	29.29	SW; NW	6.1	64	29.26
August	SW; W	6.7	67	29.24	NE; S	6.2	65	29.25
September	SW	5.6	61	29.19	NE	5.5	61	29.40
October	SW	3.7	51	29.25	SE	4.2	54	29.35
November	SW; NE	3.8	52	29.56	S	4.4	55	29.00

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this might be is Newton's (0° = 32°F., 12½° = 98°F.), and if the observations were made at noon and can thus be regarded as nearer the maximum than the 9 a.m. temperature, the old readings fit in fairly well when plotted on Newton's scale and compared with the modern Lowestoft average means of maximum temperature. The daily readings range from 0½° to 8° which on this scale would represent 34°F. and 74°F. The means for the winter months seem rather too high, considering that February and March 1674 were very severe, and this again points to an indoor exposure. The Fahrenheit equivalents to Newton's scale are given in Table II., but it is not certain that this was the scale used, for if the observations were taken at an earlier hour, this scale would make the summer readings too high.

The monthly means of the barometer readings range from 29.00 ins. in November 1674 (9 days only) to 29.60 ins. in February 1673. Obviously the readings are all too low by about 0.6 in., and the altitude of Wrentham would only reduce this error to about 0.5 in. Possibly there was some defect in the instrument, but the error appears to be constant. Dr. H. R. Mill suggests that at that time precautions may not have been taken to free the mercury from air when filling the instrument. For comparison it may be of interest to quote the following from a contemporary paper on barometer observations by Dr. Wallis[2]:—

> "The Dr. never observed the quicksilver higher than 30 ins. nor lower than 28 ins., at least within 1/16 in. of these numbers, either over or under."

The length of the period of observation is not stated, and the record appears to have been kept at Oxford, so that an altitude correction of +0.2 in. would have to be allowed for, but even then a very similar effect of general lowness in the readings is indicated. Nevertheless, Skippon's daily readings are of great interest and his additional observations on stormy days give a clear record of the intensity of the barometric changes which can rarely be available for such an early date.

One of the later general notes in the diary which is of particular interest to meteorologists describes the audibility of one of the sea-fights:

> "June 7, 1673. An Engagement between ye English and Dutch. Ye Noise whereof was heard in Norff. and Lincolnshire, and at Cambridge and Bury. Yet wee about Sowold and Lestoffe (Southwold and Lowestoft) could heare nothing, though ye wind was NE, as favourable to ye Suffolke as to ye Norff. Shore. Ye fight being at ye stone banke and Land."

The exact location of the "stone banke" is uncertain, but it must have been in a position which led Skippon to expect clear audibility on the Southwold coast. This may well be the earliest record of zones of audibility and silence.

L'Observation des Accidents de l'Atmosphère.

The *Journal de Physique et le Radium*, January, 1927, contains the results of an investigation spread over several years of the effect of discontinuous variations in density from level to level on the image of stars as viewed through an optical system. In front of the focus of the object lens (focal length 6 metres) is placed a biprism which bisects the image received (viewed by an eyepiece) into two hemispherical portions

[2] *Phil. Trans. R. Soc.*, Vol. I. (No. 10), p. 166, 1666.

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separated by a dark band. Variations in density, giving rise to striæ the effect of which is to produce dark and light patches on the image received, have various effects on the pattern seen. Some produce a mottled effect, while others give rise to a marbled appearance or to darkish bands which cross the image. It is claimed that these appearances are due to striæ (*couche troublée*), the colours of which furnish an indication of the height at which the striæ occur. It is deduced that this height shows an annual variation with two maxima (March and September) and two minima (June and December), and that there is a close relationship between this height and the weather following, the time interval of which during six years has grown progressively from 10.5 days to 17.0 days. If the *couche troublée* lies between the heights 2,500 metres and 4,500 metres, then the following days will be marked by a great increase in cloud with, in the majority of cases, rain. If the *couche troublée* is lowered or elevated, below or above these limits, then decreasing cloud will follow. *Abstract.*

Transparency of the Atmosphere in Relation to Wind, Humidity and Type of Air at Cranwell, Lincolnshire, at 13h.

In this note, Messrs. W. H. Pick and G. A. Wright examine the occurrence of days when at 13h. the visibility at Cranwell could be termed "very good." The term "very good" as applied to visibility in the scale drawn up for the use of observers is used when an object can be seen at a distance exceeding 12½ miles.[1] For the purpose of this note the authors use the expression to include visibilities of 21 miles or more, a limit which corresponds approximately to visibility L, the standard distance for which is 18⅜ miles (*loc. cit.*).

As in a previous note, the year is divided into two seasons, summer and winter (see p. 293), and the occurrence of visibility of 21 miles or over at 13h. is examined in relation to the surface winds as measured by an anemobiograph, the head of which is 43ft. above the ground, the relative humidity of the air, and the type of air prevailing, whether polar or equatorial. The data extend over a period of seven years from Jan. 1920 to Dec. 1926.

It is found that a "very good" visibility occurred on 186 occasions divided between the summer and winter periods in the proportion of two to one.

Considering wind direction separately, both in summer and winter, winds from NE give an appreciably higher percentage of occasions of "very good" visibility than do other directions with but one exception. In summer south-westerly winds give almost as high a percentage as do north-easterly winds (20.2 per cent. as compared with 20.8 per cent.). With, however, increase of velocity the percentage of days of transparent atmosphere shows a proportionately steady increase.

In winter visibility is best with a relative humidity ranging between 51 per cent. and 70 per cent., but in summer the greatest percentage frequency occurs with a relative humidity below 41 per cent., while between 41 per cent. and 80 per cent. the frequency of "very good" visibility shows little variation.

Lastly, considering the type of air prevailing at the time, polar air gives the greatest percentage frequency of clear days, but the predominance of polar air is more clearly marked in winter than in summer.

Abstract.

[1] *Observer's Handbook, Meteor. Office, London,* 1926, p. 54.

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The Weather and its Ways.

Climate. Broadcast Talk No. 5. By C. J. P. Cave.

An Englishman who had spent a fortnight in Bergen, in Norway, asked a Norwegian friend how long it usually went on raining in Bergen. "I don't know," was the reply; "you see, I have only lived here for fifteen years." Without vouching for the strict accuracy of this story, it is a fact that places on the north-west seaboard of Europe do get a great quantity of rain. At the other extreme we get places such as the coast of Chile, where there are districts whose rainfall is practically nil, and where the water supply for certain towns has to be brought great distances from the Andes mountains.

If we look at the earth as a whole we find that there are certain belts running round the globe, each belt having its own characteristic climate. Round the equator is a belt where the wind is light and variable, and where there are continual heavy rains and thunderstorms; this region is called the Doldrums, and in the old days of sailing ships a vessel might be becalmed in the hot damp weather for days or even weeks. One does not always find this wet belt in exactly the same place; during our summer it moves northward, and during our winter it moves southward; places a little north of the equator therefore get their wet weather in our summer, places to the south get their wet weather in our winter. North and south of the wet belt we get the trade wind belts, where the wind blows steadily from the north-east in the northern hemisphere, and from the south-east in the southern hemisphere. We find a steady north-east wind, for instance, blowing all the way across the Atlantic, from the coast of Africa to the West Indies, and sailing ships that want to get from England to America often sail down southward till they get into the trades and then find a fair wind to take them right across the Atlantic. North and south of the trade wind belts we get another belt of calms, but this time the calms are associated with fine weather and cloudless skies. These calm fine weather belts used to be known to mariners as the Horse Latitudes, because they were apt to be becalmed there for long periods, water might run short, and ships carrying horses had to throw some of them overboard if they were becalmed too long. It is in these rainless belts that nearly all the great deserts of the world are situated. All these, the calm wet belt, the trade wind belts, and the calm fine belts move northward in our summer and southward in our winter. Sometimes the calm, fine belt, or an extension of it, may even reach as far as our own coasts in the summer; the Mediterranean is well within its influence during the summer, and on its shores they then get a long spell of uninterrupted fine weather.

Beyond all these belts, further towards the poles we get to the region of westerly winds, in which we, in this country, live. In this belt there is a general drift of air from the west or south-west, varied, however, by depressions that move along in the general westerly drift. If you stand by a stream you may see in the general drift of the water little whirls that move along with the stream; similarly, the depressions move in the westerly current; in front of them they produce rain, and behind them is clear weather; as they pass over us they produce temporary shifts of wind, in accordance with well-known laws. Thus, in the British Islands we get very changeable weather, rain and fine alternating with each other, so that those who live in more stable climates have said that the weather in England consists only of samples; but with the

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samples we have, on the whole, a great preponderance of westerly and south-westerly winds. The depressions which cause our variable climate do not as a rule penetrate far into the continents, and there is a very marked difference between the climate of an island and that of a continent; moreover, continents tend to break up the regular sequence of the belts of climate about which I have spoken. For instance, over a great part of Asia and over part of Europe there is in winter a very persistent anticyclone, that is a region of high barometer and calm weather; this sometimes extends as far as the British Islands, and its effect is to prevent the depressions from the west from reaching our shores; it is then that we get the still frosty weather, that may last, sometimes, for two or three weeks. On the other hand, we may sometimes have in the summer an extension of the fine weather belt reaching our shores from the south; this also tends to prevent depressions from reaching us, and we then get the still warm weather that characterises a fine summer. If, however, the depressions are able to reach us, and we all know how often that happens, we get warm, rainy, changeable weather in winter and cool, rainy, changeable weather in summer. It is the south-westerly winds and the depressions that are associated with them that give us our changeable climate. But these south-westerly winds are a great boon to us; they bring warm air from the Atlantic to our coasts in winter, and in the summer they also bring us air from the ocean that tempers the heat we should otherwise experience. But it is more especially in the winter that we should be thankful for them; at this season our mean temperature is about forty degrees; but there are places in the same latitude as London, both in America and in Asia, where, out of the influence of the westerly winds, the mean temperature in winter falls as low as ten degrees below zero, or more than forty degrees of frost. We have, indeed, something to be thankful for in having westerly winds which bring us the changeable weather at which we are apt to grumble so much.

But it has not always been so; in the course of long ages our climate has changed. It is true that it is not changing much at present. If we read old memoirs, such as Pepys's Diary, we find that a couple of hundred years ago they had much the same kind of weather as we get now; a succession of very mild winters, then one or two very hard ones; sometimes a cool summer with too much rain; then, again, one too hot. But if we look back a great deal further we find a very different state of things. If we go to the Arctic regions or to the high Alps we find that glaciers, which are really rivers of ice, are carrying down stones and rocks from the mountains, and depositing them where the ice melts lower down the valleys; we find stones and rocks being scratched by the action of ice, and in many other ways we find that ice is affecting the surface of the land. If we go to the highlands of Scotland we find no glaciers, but we do find heaps of stones exactly like those formed by glaciers in the Alps; we find rock surfaces scratched exactly in the same manner as those which are known to have been scratched by ice. The conclusion is irresistible that long ago the mountains of Scotland were covered with snow and ice, not only in the winter but in the summer also; in fact, it is certain that when the climate was at its coldest a huge ice-sheet covered the north of our islands, and reached down to somewhere near the Thames; another sheet of ice reached all the way across the North Sea from the mountains of Norway and Sweden, and met the ice from Scotland; these sheets slowly moved southwards till

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they melted; on their surface they carried southward stones from the mountains of the north, and even in the south of England we find stones that can have come from no other place than the mountains of Scotland or Scandinavia, transported thence by ice. Only a few weeks ago I myself picked up such a stone on the shore near Selsey Bill, where it must have been dropped by one of the icebergs which, in those days, floated in the English Channel. This state of things came to an end very long ago; the main icesheet disappeared from Norway and Sweden some 20,000 years ago, and Scotland must have been free of ice for a very much longer period. If we look further back into the past, we find evidence that before the time of the great cold, the climate in the British Islands was considerably warmer than it is now. So we see that our climate does change, but the changes are very slow, so slow indeed that it would take many generations of men to note any difference at all. These former changes of climate, however, have had a profound influence over the evolution and history of the human race, though this is too large a question to consider now. We do not know what the future has in store; some think that we are living in a warm interlude, and that ice and snow will again have our land in their grip, that the British Islands will again become like the Arctic regions are to-day. But we need not worry ourselves about these possibilities, for the changes are so slow that even if this does happen, tens of thousands of years must elapse before it comes to pass.

Forecasting. Broadcast Talk No. 6. By J. S. Dines.

When asked to talk about weather forecasts I thought it would serve a useful purpose if I told you something of how official forecasts are prepared and of the work which is going on at observing stations scattered over the country and at the Meteorological Office in London throughout the day and night in connection with the forecast service. I think it is true to say that we always take a greater interest in things when we know something about their history and how they are made than when we know nothing about them except what we see in front of us. Take, for example, the case of coal, a commodity which has been very much in the public eye during the past summer. How many of us know anything about the getting of coal and the various processes which have to be gone through between the time when it was buried perhaps $\frac{1}{2}$ or $\frac{3}{4}$-mile below the surface of the earth and the time when it reaches our coal cellars? For this reason most of us take little interest in coal and regard it mainly as a nuisance, though one which, unfortunately, cannot be done without; but if we had been down a coal mine and seen the coal being cut, transported to the shaft, brought up in the cage and so on, we should, I am sure, look upon coal with much more interest in the future. I think it is the same with most things and that weather-forecasts are no exception to the rule.

The shepherd or other weatherwise person who makes forecasts for his own use looks at the sky and then notes what the wind and possibly the "glass" are doing, and on these observations judges what weather is likely to follow in his own locality. Now, we in the Meteorological Office have to forecast for the whole of the British Isles and for the surrounding sea areas as well, and even though we were to go on to the roof of the office, we could only see a very small piece of the sky which is covering England, so that it is clear that we cannot trust to

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our own observations alone. We have to employ people to observe for us and to post them all over the British Isles. They are to be found in lonely lighthouses and coastguard stations on remote parts of the coast, as well as in populous areas nearer home. I may be talking to some of them at this moment, and if so I should like to take the opportunity of saying "Good evening" and letting them know how much I appreciate their work. In order that we may be constantly informed of what the weather is doing, we ask these observers to be up at 1 a.m. in the morning and again at 7 a.m., and then to take further readings at 1 p.m. and 6 p.m. Taking meteorological observations on a summer afternoon or evening is a very pleasant occupation; it takes one out into the fresh air and sunshine where everyone would like to be on such an occasion; but at 1 a.m. and 7 a.m. on a winter's morning the case is very different. It is dark and cold, and very probably wet, and seeing what the clouds are like or whether the visibility is good or bad is not an attractive job. If the wind is blowing a gale so that the observer can hardly stand against it, he has, however, the satisfaction of knowing what wind to report. Having made the outdoor observations and entered the readings in a notebook specially prepared for the purpose, he goes indoors again and reads his barometer and then puts all the entries into a specially devised code for transmission to Headquarters, the complete message consisting of some six groups of five figures each, or thirty figures in all. This code has been the subject of international agreement and is used in its essentials throughout most of Europe. The message when compiled is either telephoned or taken by hand to the nearest telegraph office for despatch to London and the observer's responsibilities are over for the time being.

The Post Office does not take long to deliver the telegram, and a short time after the observer has completed his work, our responsibilities in London commence with its arrival.

We will turn our attention to the forecast rooms in the Meteorological Office. Telephone clerks receive the messages which are telephoned from the telegraph office instead of being delivered by hand. They make several copies of each message, one of which goes to the forecast table, while the others are used for purposes with which we are not now immediately concerned.

The forecaster who is on duty could not possibly remember the contents of all the messages which come in, even if he did read them through (there are forty observing stations in the British Isles), so he gets someone to enter the different observations on outline maps, so that when he looks at these maps he can see at a glance that, for instance, it is raining hard and blowing a gale at Wick, in the north of Scotland, that the glass is low and falling very rapidly on the Irish coast, and that the sky which has been clear in the south of England is beginning to cloud over.

Now, I may have seemed to suggest that our methods of forecasting are the same as those of the shepherd except that we get other people to look at the sky for us. This is not true. We attach, as he does, great importance to the state of the sky and to the wind; but we also draw on our map lines called isobars which tell us where the barometer is low and where it is high, so that we can tell you, as we so often do, that there is a depression off so and so, that is, that the barometer is low in that region, or that there is an anticyclone somewhere else, that is, that the barometer is high there. These isobars are of fundamental

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importance in our work. We find that the depressions and anticyclones tend to move in certain directions and to carry their weather with them, so that a depression moving from the Atlantic to London will bring its bad weather with it, and that if it is followed by an anticyclone, we may in the summer, at least, expect some finer weather to come.

Owing to the movement of these weather systems it is not enough for us to have reports from our forty stations in the British Isles; we need to know what is happening over the Atlantic, on the Continent, and even in Greenland and America. All this we learn from the observers in the various countries and from our sailors who record the weather as they cross the Atlantic in ocean liners and send us wireless messages reporting their observations. Within a very short time of the hour of observation, the forecaster, then, has in front of him a map showing the weather over a wide area, and such a map will nearly always have upon it several separate weather systems, depressions and anticyclones, each with its own motion and, one might say, its own individuality. Some of these systems seem as self-willed and as unwilling to obey the laws laid down for them as any human being.

Let us consider one of these systems, say, a depression, as these are more active and more interesting than their neighbours, the anticyclones. The forecaster knows from the chart where the depression is situated and what weather it has around it at the moment. He has to make up his mind which way and at what speed it will move so that he can say that to-morrow morning it will be in such and such a place. Also, he has to be able to say how the weather it carries with it will change as time goes on. A depression is a very live thing and seldom keeps its weather the same for long at a time. It is either growing more active or feeling the effects of old age and becoming less active in producing rain and wind; or it may be changing its shape and pushing out what we call a secondary in one direction or another. Thus, to take the case of the depression moving from the Atlantic to London, when it reaches London it may be in the prime of life and be blowing down chimney pots and flooding the streets with rain, or it may have lost nearly all its activity and produce little more than cloud and drizzle. There is, then, plenty of room for the skill of the forecaster.

I have tried to give you some idea of how we make forecasts. There is sure to be some person saying, "Well, your forecasts have been bad enough in the past; can you give us any hope of making better ones in the future?" I don't, of course, agree with the first part of the grumbler's remark, but I will try to answer his question.

The atmosphere in which our weather changes occur is not the air we feel blowing past our faces on the ground, but is a sea of air many miles deep. Our observers tell us what is happening on the earth's surface. We have in the past known next to nothing of what was happening up above in the real home of the weather. Observations of temperature, etc., taken by means of aeroplanes are helping us to get more knowledge of the upper air conditions, and while it may be a long time before we get all the knowledge which we should like to have, the reports we are getting and the scientific study which is being devoted to them cannot fail to lead to a gradual decrease in the percentage of forecasts which go wrong, though that percentage, if judged fairly, will be found not to be very high, even at the present time.

September, 1926.

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On the Calibration of Pressure Tube Anemometers.[1]

In a note[2] on the above subject by R. G. Veryard which appeared in the *Journal* for 1925, it was shown that a combination of the Dines formula

$$W = .093\, v^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the formula

$$P = \tfrac{1}{2}\rho V^2 (1 + K) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

gave an impossible value for ρ, the air density, when an average value of K was substituted in (2). In the above formulæ W is the pressure in mm. of water due to a wind of velocity v metres per second, P is the total difference of pressure in C.G.S. units between the pressure and suction outlets of a Dines anemograph head in a wind V cm. per sec. and density ρ, while K is the ratio of suction to pressure.

In view of the fact that the value of the constant in formula (1) was determined by W. H. Dines by direct experiment under conditions in which ρ could not have been very different from the normal, it was difficult to understand how this discrepancy could have arisen. The explanation has recently been furnished by some experiments carried out at the National Physical Laboratory on behalf of the Meteorological Office.

We may begin by expressing (1) and (2) in C.G.S. units when we obtain the relationship

$$P = .000912\, V^2 = \tfrac{1}{2}\rho V^2 (1 + K)$$

or

$$\tfrac{1}{2}\rho (1 + K) = .000912 \quad . \quad . \quad . \quad . \quad (3)$$

It will be seen from (3) that for a Dines head with a given value of K the value of the constant is dependent upon the density of the air. Unfortunately, we have no record of the standard value of ρ to which the Dines constant is applicable, but we may obtain an approximation to the value of K by taking the standard density .001225 gm/cm^3 corresponding to 15.5°C. and 760 mm. This gives $K = 0.490$.

The heads referred to in R. G. Veryard's note had a value of K about 0.33 determined in a wind tunnel at the National Physical Laboratory. It has now been ascertained that the apparent value of K is very largely influenced by the presence of anything which causes a disturbance in the flow of air past the suction holes. In particular, the measured value of K was much greater with the vane in position than when the head was exposed without the vane.

For some years past it has been customary to have the heads tested without the vanes and the values of K quoted by R. G. Veryard refer solely to such tests. The fact that the vane might appreciably affect the result does not seem to have been mentioned until 1924, when the National Physical Laboratory expressed the view that the flow round the vertical suction tube would probably be affected by the moving vane and that tests made without the vane must not necessarily be taken as valid for the complete instruments in working conditions. No change was made at that time, however, partly because it was not supposed that the effect of the vane was large and partly because the calibration figures were only used for purposes of comparison. It is clear, however, that

[1] Note prepared in the Instruments Division of the Meteorological Office.

[2] R. G. Veryard "On the Calibration of Pressure Tube Anemometers," *Q.J. Roy. Met. Soc.*, **51**, p. 413

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to construct a complete calibration curve for head and receiver together it is necessary to know the true working value of K.

Another fact learned from the tests at the National Physical Laboratory was that the projecting bends at the base of the head, for connecting the pressure and suction pipes, caused a variation in the value of K for different orientations. The effect could be eliminated by shielding the base of the head. The best results were obtained with a cylindrical shield surmounted by an ellipsoidal top, the summit of which was 0.75 inch below the lowermost row of suction holes. With such a shield a typical head gave a value of $K = 0.478$, in close agreement with the value required to satisfy Dines' formula.

E. G. BILHAM.

Meteorological Office,
Air Ministry, W.C.2.
May 4, 1927.

The Glacial Anticyclones.

To the Editor: It is said of great offenders against the law that even when guilty of major crimes they exhibit considerable resentment when charged with minor offences they have not committed. It is because in a review of my *Glacial Anticyclones*[1] I have been placed in the unpleasant position of being charged with errors concerned especially with nomenclature, but of which I am not guilty, that I ask your favour to put myself right before your readers.

My very eminent reviewer, Sir Napier Shaw, has devoted the greater part of his three-page review to criticism chiefly of my assumed improper use of two expressions—anticyclone and fœhn. As regards the former term I have not used it at all in its unmodified form and the word is not to be found in my ten-page index. I have, moreover, been at much pains to explain that the earth's two *glacial anticyclones* (these terms always used together as one expression) are important parts of the general circulation, are of vast dimensions, maintain a fixed position, and have really little in common with anticyclones proper beyond the sense of direction of the whirl and the fact that the air within is descending. Dr. Mill in his introduction to my monograph has, further, striven to prevent the very misinterpretation which my reviewer has made. Most of his difficulties disappear when he is set right upon this point.

Sir Napier would discuss the great unified circulation of the glacial anticyclone as local and occasional (what he calls katabatic) winds, and goes on to charge me with describing these winds "under the fettering title of polar anticyclones." I have never been guilty of using the term "polar anticyclones," as a careful perusal of my monograph should have shown. In fact, I have inveighed against the use of this idea more vigorously even than Sir Napier himself, for example on p. 122.

It is because we know so little of the intervening layer of air between high inflow and low outflow over the ice-cap slopes that I have (in my sketch on p. 51) shown this intermediate layer as it "looks on complacently, taking no part in the game." My present view is that it is in a relatively quiescent condition, but I hope during the present season to succeed in sending up both pilot and captive balloons from the ice surface with a view to derive some real knowledge of it.

[1] *Q.J.R.Meteor.Soc.*, Jan., 1927.

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Sir Napier has also criticised an asserted confusion of fœhn winds with valley winds. I have not even once used the term valley winds and believe it a mistake to institute such a comparison. I am averse to replacing the time-honoured and excellent term fœhn by Shaw's term "katabatic wind." I have used fœhn in the sense of down-slope winds, what the Germans often refer to as *Fallwinde* and we as slope-winds. To me it appears a great advantage to keep these terms free from theories of origin, for fœhns, slope-winds or *Fallwinde* have the well-defined characters of dryness and relative warmth and are accompanied by clear skies; all of which characters are obviously a consequence of adiabatic change due to the descent of the air.

Though I hesitate to oppose so eminent an authority, I must assert that fœhn winds are in all cases not *potentially* warm winds—as Sir Napier asserts—but *actually* such. With my exploring party I was on August 1, 1926, on the Greenland ice-cap near its western margin while a strong south-east fœhn was blowing down the slope. In the far interior the air temperature (to judge from observations by J. P. Koch) was probably as low as −30°C., and this wind had actually crossed over hundreds of miles of ice surface, yet it had become so warm from its descent that we found the wearing of gloves decidedly uncomfortable.

Against my replacing the term fœhn by katabatic wind is the fact that the slope-winds of Greenland—the most remarkable slope-winds yet known—have by all the eminent meteorologists who have studied them been designated as fœhns, and the accompanying clouds as "fœhn clouds."

In his penultimate paragraph I believe that my critic has perhaps confused "might" with "right." He says: "The general circulation . . . always reserves the right to blow away the glacial anticyclone or anything else that gets in its road." The glacial anticyclone in my belief *is* a part of the general circulation, and while it may have the *right* ascribed to it, it apparently lacks the *might* to "blow itself away." It passes indeed through changes within itself accompanied by transformations of energy well accounted for by the known laws of thermodynamics, and these develop pulsations or *strophs;* but by no stretch of the imagination can the glacial anticyclone be said to be blown away by the general circulation.

W. H. Hobbs.

OBITUARY.

Dr. John Brownlee, M.D., D.Sc.

The Royal Meteorological Society has recently lost one of its most enthusiastic Fellows in the person of Dr. John Brownlee, who died on March 20 after a very brief illness. Dr. Brownlee was educated at Glasgow High School and the University of Glasgow, where in 1889 he graduated in Arts with first-class honours and was awarded the Eglinton Fellowship. Proceeding thereafter to the study of medicine, he graduated M.D. in 1897 with distinction. After leaving the University he took up public health work and was for nearly twelve years Physician-Superintendent in the Glasgow Fever Hospitals. During this period he published numerous papers on epidemiological and biological subjects. In 1907 he graduated D.Sc. at the University of Glasgow, his thesis comprising a series of papers entitled "Statistical Studies in Immunity."

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In 1914 Dr. Brownlee came to London as Director of Statistics to the Medical Research Council, and in the same year was elected a Fellow of this Society. He served on the Council in 1920 and again from 1922-1925. After coming to London, Dr. Brownlee's scientific output was very considerable. Forty-five of the eighty papers and memoirs comprising his complete bibliography appeared subsequent to 1914. He made a special study of periodicity in weather phenomena with the view of correlating this feature with cyclical changes in disease and was engaged shortly before his death in an investigation to determine a better method of eliciting these relationships than that hitherto generally used.

Dr. Brownlee was a man of powerful intellect and wide culture. He was invariably ready to enter freely into a discussion on any subject, not only in his own field of medicine and science, but gladly accepted opportunities to make excursions into the fields of literature, art and music, where he was equally at home. All who were fortunate enough to come into intimate contact with him soon developed a sincere respect for his great endowments and regard for him as a man, and his loss will be felt greatly in the circles in which he moved.

REVIEWS.

Manual of Meteorology. Volume I., *Meteorology in History.* By Sir Napier Shaw, LL.D., Sc.D., F.R.S., with the assistance of Elaine Austin. Cambridge (University Press), 1926. 8vo. Pp. xx + 339, pls. 8. 30s. net.

It has been remarked on more than one occasion that the leading scientific men of this country have been concerned with the active prosecution of research rather than with the description, in encyclopædic form, of what is to be known in their respective subjects, and that the compilation of the *Handbuch* has generally been resigned to the Teuton. Whether this process has always resulted in the circulation of impartial history is matter for debate. Now, however, we have the promise—with its partial fulfilment—that in meteorology, at least, we shall have a full account of the science from one who for many years has been its leader in this country and who brings to his task a remarkable combination of exact knowledge and breadth of outlook with the rarer gift of lucid exposition.

The general purpose of Sir Napier Shaw's *Manual* is stated clearly in the Preface. Its author felt that his "work for the science could not be regarded as finished without a definite attempt to rescue from oblivion the vast mass of information about weather that is hidden behind the backs of books in a meteorological library"; "to represent the knowledge which the reader of a paper on meteorology before a learned society of the present day will assume, perhaps unconsciously, to be in the possession of his audience"; to enable amateurs—or, rather, the non-official students of the science—to "obtain access to a point of view from which they can survey the aims and objects within reach"; and "to put the actual facts before the reader and let him draw conclusions for himself."

With these laudable objects, Sir Napier has issued the first of four volumes. It is devoted to a study of the historical development of ideas connected with the science, beginning with weather and climate as understood by the writers of classical antiquity and passing through the times of Aristotle, the later classical writers, the Middle Ages and their weather lore, Galileo and Torricelli, until we reach the age of the weather map, the daily forecast, and the demands of an evil generation that seeketh for a sign. Had it been intended as a history of the science, the hyper-

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critic would, as the author foresees, have revelled in its supposed omissions. He would have complained that Sir Napier Shaw has not gone back to the beginning, inasmuch as he omits mention of the Chinese rebel[1] who produced a fog in 2634 B.C.; that there is no reference to the earliest recorded application[2] of meteorology in naval warfare when the Athenian admiral, Phormio, waited for the land breeze out of the Gulf of Corinth before beginning the battle of Naupactus; that Bacon should have been credited with the earliest advocacy of high level observatories; that while Mayer gets his due meed of praise, the name of Joule finds no place; and that the *perfervidum ingenium Scotorum* is not placated by any mention of Ben Nevis, and so forth. But much, if not all, of this would be misdirected criticism, for the book is not and is not intended as an exhaustive history. Rather is it a survey of the attitude of the human mind in different ages towards the problem of weather, its changes and their causes. And whether we are dealing with the early Aryans and their invocation of the rain-god Indra in the Vedic hymn, or with the General Assembly of the Church of Scotland when a severe thunderstorm was regarded as a "visitation" during a famous ecclesiastical debate, this attitude must always be of interest. Viewed in this broader light the volume is a valuable contribution to literature, not only on account of what it includes, but also because of the somewhat unusual, though none the less effective, manner of presentation. The historical treatment of a science can be, and occasionally has been, the dullest of literary productions. The general method has been to envisage the mental outlook of each successive age or period and to draw the mind of the reader into a sympathetic parallelism with it. But a history of ideas in which each is assigned its proper place by a constant reference to modern knowledge is no ordinary compilation, for it requires a sanity in judgment and an art in expression that is given to few. Take, for instance, the author's account of the science as understood in classical times. Preceded by a brief summary of the methods of expressing the meteorological elements and by a chapter on the kalendar and the cycle of the seasons, we come to the meteorological references in the poets, philosophers and historians of antiquity down to the time of Aristotle. Throughout, the reader is seldom allowed to forget that he is living and thinking in the twentieth century. The first line of p. 72 quotes Hippocrates (400 B.C.), but the same page brings us back with a jerk to the Bakerian Lecture of 1892. The description by Herodotus of the Scythian climate is immediately followed by recent statistics as to the frequency of snow, rain and thunderstorms in the Crimea, and the Father of History is once more supported by modern knowledge. Inevitably, of course, there are links that are missing from the chain and that cannot now be supplied. Had the annals of Tyre come down to us complete, instead of the scraps quoted by Menander and repeated by Josephus, we might have known what the intrepid Phenician circumnavigators of Africa thought about the monsoons, and been able to compare this with the better informed knowledge of to-day.

From the *Meteorologica* of Aristotle we pass to his pupil Theophrastus, to the *Georgics* of Virgil, down to mediæval weather lore, and again we find our author contrasting the older with the newer view. We thus reach the age of the barometer and thermometer. At this point there is interposed a series of short biographical notices of the pioneers, from 1643 to 1860, of the now dawning science, and the interest in these is not lessened by Sir Napier's occasionally piquant comments. Of Galileo's teachers he says: "To their narrow ideas a philosopher only needed to know Aristotle by heart; to understand him was a secondary considera-

[1] Klaproth. *Lettre à M. le Baron Humboldt sur l'invention de la Boussole.* Paris, 1834.

[2] Thucydides. Bk. II., Ch. viii., 84.

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tion; to contradict him was a blasphemy: Galileo both understood and contradicted." As to Dalton there is the diverting statement that "he never had time to marry, but he got through an astonishing amount of scientific work." Sound reasons are given for the inclusion of such biographical notices and to these another might be added. There is a thinly veiled hint in the book that the meteorology of to-day—or, at least, the public interest in it—is more concerned with the chances of a successful forecast of the morrow than with the rational explanation of yesterday. If this be so, it is well to be reminded of the men who, unaffected by such temptations, laid the foundations upon which the science now stands. They sought for physical fact as "something true and good for ever, not a mere outcome of craft and expediency."

About halfway through the volume we reach the beginning of Sir Napier's treatment of meteorology as it is known to-day. As to the best plan for such treatment, opinions may and probably always will differ. Some writers may be cramped for space; others may have particular views to emphasise or novel theories to promulgate; while we have always with us that numerous class to whom the survey of the field is more important than its cultivation. Sir Napier Shaw is, happily, not subject to any such limitation or disqualification, and thus we have a method of exposition which is not only characteristic but entirely new. It begins with a chapter on meteorology as an international science, and with important reflections on the exact purpose of meteorological observations. "Briefly stated, these are, first the compilation of observations to be co-ordinated into a faithful representation of the general circulation of the atmosphere and its changes; secondly, the identification of the dynamical and physical processes by which the changes are brought about; and thirdly the exposition of the sequence of changes as the result of the physical processes involved therein." The author then proceeds to the elaboration of what may be taken as his main thesis—that meteorology is the study of a world-wide problem; that its organisation must correspond to its character and be adequate to its needs; and that, until this is secured, contributions to meteorology must remain as "marginal notes on a text that does not exist." In a particularly interesting passage he sketches the different avenues of approach to this great question and shows that they all lead to the same conclusion, that "meteorology is now approaching, if it has not already reached, the parting of the ways where it must either be content to achieve a success something better than the Shepherd of Banbury's, but of the same type, or advance boldly to a real knowledge of the structure of the atmosphere and its changes. . . . Then we may really understand weather." To secure this latter step there is advocated the establishment of an international weather office, charged with the duty of co-ordinating and studying all meteorological information apart from what is required for the special economic necessities of any particular country. The present is scarcely the appropriate occasion for the examination of this proposal, nor is the writer qualified for the task. But it may be permissible to suggest that while his proposal for the future advance of the science is obviously sound, Sir Napier Shaw would have been on firmer ground had he not invoked as an example the parallel organisation in international politics, the League of Nations. An international meteorological college for the study of world weather would not become a focus of mischievous interference, activated by long-haired cranks.

The remaining chapters of the volume are devoted to the means and methods for the study of the surface air and the upper air, the energy changes in the atmosphere, arithmetical and graphical manipulation of statistical data, and finally with the historical aspect of the general circulation problem and a brief review of meteorological theory in history. These chapters are examples of the general method followed throughout.

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They are not concerned with the technique of observation or calculation; for such purposes references to instructions already published are provided in abundance. But they explain as no other treatise does the general purpose of each observation and its relative importance in the scheme of the science as a whole. Yet the essentials are all here. For instance, the first of the sections dealing with observational means and methods is rightly concerned with the measurement of time, and it is pleasing to observe that Sir Napier has nothing whatever to say on that monstrous absurdity known as "Summer Time." The classification of cloud forms is treated in considerable detail and is amply illustrated by well-chosen photographs. The adequacy of the present international classification is commented on at some length. The author has been impressed by the frequent arrangement of clouds in line, sometimes in parallel lines and occasionally in cross-parallels. He therefore suggests a reclassification according to the cloud unit of which the form is composed and to the manner in which the units are grouped. The chapter on the analysis of air movement into the general circulation and the cyclone is really intended as an account of the historical development of the synoptic weather map, the fuller treatment of the whole question being reserved for Volume II. The final chapter, dealing with meteorological theory in history, reverts again to the problem of the general circulation of the atmosphere, and indicates the line of attack which, in the author's view, will allow of the most rapid and nearest approach to the grand synthesis of all weather knowledge. That approach is not to be secured by any assumption, as to the convection of warm air, that cannot stand numerical tests, nor by the hypothesis of an idealised atmosphere to which the laws of motion of a perfect fluid may be supposed applicable. It will only be possible by a wide induction, based on observation, and leading up to some definite thermal or dynamical theory. It is with this third view that the author is most in sympathy and he promises to develop it more fully in a later volume.

There is much more in this volume than is listed in its "Contents" or in its index, for the wide generality in treatment of his subject has allowed the author to express himself freely. Yet his generalisations—and there are many—are never sweeping, for they constantly recognise the restraint of ascertained fact. Above all, the serious discussion of a difficult subject is made attractive by the brilliance of its literary setting, for there is throughout a command of felicitous expression which all its readers will enjoy. Their best wishes are for Sir Napier Shaw's continued health and strength for the completion of his great work.

A. CRICHTON MITCHELL.

Climate through the Ages. A study of climatic factors and climatic variations. By C. E. P. BROOKS, D.Sc. London (Ernest Benn Ltd.), 1926. 8vo. Pp. 439, illus. 15s. net.

There is, to-day, always a risk that specialists in two subjects, using languages full of words that are unintelligible without study, will grow up not only, without knowledge of each other's work, but also will ignore the problems which require mutual assistance. It is not often that a professional geologist reaches distinction in meteorology, as Blanford did to an eminent degree; and it is fortunate that Dr. Brooks adds to the dual qualification the faculty of clear and incisive exposition.

In his former book *The Evolution of Climate* the "causes of the events described" were "touched on very briefly," so that there would from time to time obtrude itself on the reader a desire for a fuller treatment of the problems involved, geological as well as meteorological—in fact, for a book on the same lines as at present.

The subject is divided into three parts; first the climatic factors and their variation, second geological climates and their causes, and third the climate of the historical past.

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The first chapter contains the author's chief contribution to the subject, that under certain conditions a small lowering of temperature in polar regions will produce an ice-cap which exerts a further cooling effect and grow to a much greater extent than would be due to the initial conditions: the ultimate lowering of the winter temperature brought about by a fall of temperature of only 0°.6F. may amount to about 45°F., and conversely a small rise in the general temperature would cause the polar ice-cap to disappear every summer, as probably occurred from 400 to 600 A.D.

In the next two chapters we have an account of the general circulation of the atmosphere and the oceans with interesting inferences regarding the winds and currents in glacial and non-glacial periods. Then come very interesting studies of the effects of changes in solar radiation, including Humphreys's suggestion that at sunspot minima a diminution of the corona leads to an increase of ozone and a slight warming; there are also studies of purely astronomical factors such as the eccentricity of the earth's orbit: Köppen and Wegener adopt the latter for the succession of glacial periods during the Quaternary Ice Age, but Brooks regards the chronological agreement as insufficient. Among the various proposals of interpreting glacial periods in terms of absorption of radiation the effect of long periods of volcanic dust is treated as possibly promising, though inadequate to account for the warmth of the interglacial epochs. Chapter VIII. contains investigations by Spitaler, Brooks and Kerner with the object of deducing temperatures from geographical situations, and from these follow determinations of winter and summer temperatures during various geological periods; light is thereby thrown on the warm periods in northern Europe ending about 900 B.C. and about 1200 A.D. We then have estimates of the dates of the main epochs of mountain building which appear to have preceded the glacial periods, and with the theory, largely due to W. Ramsay, of the effect of the one on the other: and this section of the book ends with a picturesque description of the weather in the warm periods.

Part II. begins with a bold and impressive derivation of mean temperatures in past eras from estimates, based on the work of several geologists, of continentality, the average land elevation, ocean currents (measured by widths of land-gaps at 60°N.), and volcanic action. The curve of mean temperature derived from these by an application of statistical methods agrees extremely well with a curve of past temperatures based on estimates by E. Dacqué; but the agreement can scarcely be regarded as affording proof of the correctness of the explanation given unless Dacqué's estimates were founded on independent information.

The question of continental drift is of fundamental importance; if we are given *carte blanche* to shift our land areas as we wish, we can obviously explain many anomalies. It may be that Wegener has gone too far: but the usual and apparently valid objection to his theory—that the forces tending to produce motion are inadequate for their task—cannot justify scepticism regarding drift in general in view of the hundreds of miles of motion necessary for the crumpling of the Alps. In Chapter XIV. Brooks discusses the climatological evidence and points out that the glacial deposits of the United States at a time when that region should have been equatorial is almost as great an obstacle to the drift theory as the glacial deposits of equatorial Africa form to the assumption that the continents held their present positions. Further, the positions of deserts in the past are so nearly coincident with those of to-day as to make Wegener's interpretation unlikely; nor does the recent information from the British Antarctic Expedition support it.

In the next chapter a brave effort is made to explain the glaciation in Africa and India of the Upper Carboniferous period in terms of the geography of Gondwanaland, which is supposed to rise to 10,000 or

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15,000 feet; but the difficulty of producing a glacier large enough to reach down to sea level on the northern edge of the tropics is considerable and is not entirely removed.

After the more strenuous task of reconstructing the remote past from the inevitably scanty materials available, it is an agreeable change to turn to more recent times and to realise that within the past 7,000 years there have been, although many are unaware of the fact, climatic changes big enough to affect racial movements. It is now supposed, for example, that the central European lake-dwellings were established at so dry a period that they were not in the lakes themselves, but on peat-bogs now under water; it is practically certain that when Greenland was colonised in the tenth century the climate was much milder than now; and by piecing together evidence from sources of many kinds Brooks derives curves of rainfall variation from B.C. 5000 for Europe and for western Asia, which are similar to a surprising degree in view of the fact that after 1000 B.C. they are constructed independently from different kinds of data. In America, the sequoias of California enable climatic fluctuations to be traced, probably in broad outline at any rate, back to 1000 B.C., and a certain amount of independent evidence can be obtained from fluctuations of the American lakes.

There have been during the historical period several fluctuations of quite appreciable magnitude; their interpretation demands a knowledge of solar activity in place of which we have only fragmentary accounts of spots and auroræ before Wolf's series in 1749; and it is surprising that some correspondence with rainfall fluctuations can be traced. Brooks concludes that while the shorter fluctuations are directly related to changes in solar radiation, the long period swings have their origin in conditions in the Arctic Ocean.

The book deals from cover to cover with subjects of which the data are scanty and the physics complex. The fundamental problem of the cause of glacial periods had been laboriously examined from various sides and all explanations offered raise very great difficulties, so that Dr. Brooks must not be discouraged if one or two of the more speculative suggestions to which he has given countenance do not command general assent: and he has made an important contribution to the solution by showing the climatic effect at any place of the distribution of land and of ice in its neighbourhood. The book contains a large amount of interesting and often unexpected information, obviously derived from an extensive and penetrating study of materials from many sources; it has bearings on social and historical as well as on physical questions; and it is to be commended for its stimulus and suggestiveness as well as for the wide knowledge that it displays.

G. T. W.

Uber Niederschlag und Abfluss im Hochgebirge. Sonderdarstellung des Mattmarkgebietes. Ein Beitrag zur Fluss- und Gletscherkunde der Schweiz. Von OTTO LUTSCHG. *Zürich, Schweiz. Meteor. Zentralanstalt, Hydrologische Abteilung, Verbandsschr.* No. 14, 1926. 4to. Pp. xx + 480, pls., maps, chts.

This imposing volume is a compendium of information on the natural movements of water in Switzerland. It deals with the rainfall and snowfall on the one hand, and the hydrology of lakes, rivers and glaciers on the other. It is most beautifully printed and is illustrated with a fine set of maps and photographs. The discussion is carried into great detail, numerous sets of observations being quoted in full and many tables of results provided.

To the meteorologist, interest centres in the chapters dealing with the rainfall and snowfall. One is impressed by the difficulties with which the measurement of these quantities is beset. The gauges are

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often placed in most inaccessible positions, rendering the work of the observers extremely arduous. There would appear to be little attempt to secure what we would call "good exposures" for the gauges. They are often placed on the extreme summits of mountains, the ground falling away very steeply on one or more sides; and although the gauges are provided with a form of Nipher shield, there can be no doubt that in such situations they are over-exposed and record far less than the true fall. For the actual fall on a mountain summit is not representative of the fall of the neighbourhood except when the air is calm, since a considerable amount of the snow or rain precipitated in a wind is carried away from the summit by the upward component of the wind which is produced by the obstacle of the mountain itself. Indeed, some of the photographs bear eloquent testimony to this effect, for they show gauges on mountain summits of which the windward slopes are quite bare, while the leeward slopes are deeply covered with snow. This problem of finding a good exposure for a raingauge in a mountainous region is an extremely difficult one. The fact that over-exposure occurs in some places involves as a necessary consequence the counterbalancing fact that under suitable conditions of wind, under-exposed positions also occur where the fall is in excess of that proper to the locality. Such positions may, however, be over-exposed to winds of another direction. The gauges are all supported some distance above the ground in order to avoid the risk of being buried in snow. This unavoidable circumstance provides an additional cause for loss owing to over-exposure.

There are, in addition, chapters on the general climatology of the region, which are based on data supplied by the Swiss Meteorological Service, and are of considerable interest.

R. C.

Fogs and Clouds. By W. J. HUMPHREYS. London (Baillière, Tindall & Cox); Baltimore (The Williams Wilkins Co.). 8vo. 1926. Pp. xvii + 104, pls. 96. 18s. net.

This is a very readable and beautifully produced introduction to the study of clouds and fog which ought to be put into the hands of the artists who adorn the walls of our picture exhibitions with caricatures of sky scenery. It is written throughout in the simplest language. Meteorological terms such as "lapse rate" and "troposphere," and even physical terms like "adiabatic" and "isothermal," are absent from the index and the text. Indeed, there is nothing to repel the uninitiated, while the wealth of illustrations (chiefly borrowed by the author) is bound to attract the beginner, and cannot fail to please the meteorological expert.

There are only 98 pages of the text, which include short accounts of the lives of John Aitken and Luke Howard, and a chapter on what the author calls "Cloud Splendours." The part devoted to clouds is thus narrowed down to about 60 pages, so that meteorologists will not expect to meet with much discussion of the causes which bring about the special forms and types of cloud.

One suggestion Dr. Humphreys makes in his preface. He realises that the International Scheme of Cloud Nomenclature, which he rightly adopts, is not detailed enough for some purposes. Thus he gives illustrations of several varieties of cirrus. In the preface he says:

> "It is believed that a much closer approach to agreement among cloud observers . . . could be had by matching cloudscapes with cloud pictures instead of naming them. To encourage such matching, for agreement is vital to understanding and profitable use, and also to facilitate recording and reporting an arbitrary symbol *ac*, *db*, etc., in which the first letter stands for the type and the second for the class, is given to each cloud represented."

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Now, if some authoritative body such as an International Committee were to draw up an atlas of varieties, there might be something to be said for this proposal. But even then it is surely much more easy to remember a name which is more or less descriptive than it is to recollect whether it is *a*, *b*, *c* or *d*.

Among the very numerous illustrations there are some thirteen of cirrus with varieties from *a* to *g*. Fortunately for his readers, the author gives the special names which have now come more or less into use. Anyone can see how much easier it is to remember these names.

Some of these cloudscapes are extremely beautiful, but others do not show plainly the special structures from which the name is derived; and among the "Cloud Splendours" there appears a picture of a halo and parhelic circle about which there should be some explanatory text. We note that the halo is not circular, but distinctly longer horizontally, and the parhelic circle appears to have a radius of about 22° and to be very far from parallel to the horizon, as the text very rightly says it should be.

But this is a small detail. Everyone will enjoy the beautiful photographs of fog and cloud among the Californian mountains from the camera of F. Ellerman, and there are numbers of most interesting pictures by other observers, such as the table cloth on Table Mountain and the photographs of tornado clouds.

It is an admirable book for the uninitiated, and makes no attempt to go beyond the elementary stage, so that both author and publisher should find a wide circle of readers. It is very well got up, and the photographic reproduction is excellent.

The number of people who think about the clouds and their meaning is small indeed, but this book should add many recruits to their ranks.

ARTHUR W. CLAYDEN.

Wetterwellen. Zur Kenntniss der langwahrenden Witterungsperioden. By Prof. L. DANILOW. Ukrmet, Kiev, 1926. Pp. 212. 8vo. Russian; German summary, pp. 187-212.

The isobars on a daily weather chart present features having various degrees of stability, from the rapidly changing secondary depressions through the more persistent primary depressions and anticyclones to the semi-permanent Icelandic low and the Azores anticyclone. Prof. Danilow discriminates between these different features by constructing pressure charts to represent means over $2\frac{1}{2}$ and five days. Thus the charts showing $2\frac{1}{2}$-day means are much simpler than the daily charts owing to the smoothing out of the secondary features, and to the "depressions" moving eastward more regularly and more slowly than those of the daily charts. Conversely, the charts of the differences between the $2\frac{1}{2}$-day means and the individual observations (termed "baroisanomals of the first order") bring out the secondary features; they resemble isallobars and move eastward very rapidly. The differences between the $2\frac{1}{2}$- and five-day means ("baroisanomals of the second order") are similar but the elements are larger and move more slowly. The charts of five-day means begin to show traces of the semi-permanent anticyclones and lows, and in place of the eastward movement of centres there is a kind of pulsation, waves of rising or falling pressure spreading out from various centres.

The second part of the paper consists of a rough periodogram analysis of pressure data from a number of places in Europe, from which the author finds waves of 5-6, 7-9, 11-14, 20 and 30 days, apparently corresponding with Defant's rainfall waves of 5.7, 8.7 and 12.4 and 24 days. In opposition to Exner and Defant, however, he regards them as stationary waves or pulsations, their centres being separated by neutral zones, and instead of Defant's simple series of 24-12-8-6 days he adopts

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a system of "overtones," obtained by dividing the primary period of 30 days successively by the roots of 1×2, 2×3, 3×4, etc. This gives periodicities of 21.2, 12.2, 8.7, 6.7 and 5.4 days. Similarly, he regards periodicities of two to eight months as overtones of the annual variation. The paper contains a great deal of interest, and though some of the conclusions are unconvincing, the whole may be regarded as a definite contribution to the rapidly growing literature of "medium-range" forecasting.

C.E.P.B.

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THE RANGE OF ATMOSPHERICS.

A REPORT FROM THE COMMITTEE ON THE RELATION BETWEEN ATMOSPHERICS AND WEATHER.

[Read at a meeting of the Society on April 20, 1927.]

I.—INTRODUCTORY.

As has already been noted in the QUARTERLY JOURNAL,[1]* the Council of the Society received from Mr. R. L. Latcham, of the cable ship "*John W. Mackay*," a communication calling attention to the possible uses as aids to weather forecasting of observations on naturally occurring electro-magnetic waves, now commonly called atmospherics, which are so familiar to all wireless listeners. The letter contained a statement of criteria by which forecasts might be based on such observations. These criteria were substantially similar to those given by Franck-Duroquier[2] and Delval[3]. The Council after consideration of this letter appointed a committee to consider whether observations on atmospherics might be of service in forecasting, and more generally to investigate and report on the relation between atmospherics and weather. The Committee comprised the following members, namely:—C. J. P. Cave, D. Brunt, M. A. Giblett and R. A. Watson Watt (convener). The Committee addressed itself in the first instance to the task of examining the published literature of the subject, the main body of which was summarized in a Bibliography to be found in the QUARTERLY JOURNAL.[1] The Committee was impressed by the extreme divergence of opinion on the fundamentals of the subject revealed by this examination, particularly as exemplified in the widely varying estimates of the distance from its source at which an average atmospheric may be heard in a normal radiotelegraphic receiver. While this divergence remained unresolved, the Committee could not select a rational réseau for the comparison of atmospherics and weather, since, were the lower estimates of range correct for the majority of atmospherics, then the British *Daily Weather Report* would be of a mesh too open to be of use in the investigation, while if the higher estimates were more usually true, then the synoptic chart for the Northern Hemisphere would not suffice to embrace the area from which atmospherics might be received in Great Britain. As an element in forecasting, too, the short range atmospheric would clearly be of little or no value save in extremely short range forecasting, since the discontinuity from which it was radiated might arrive almost immediately after it. The published evidence as to the range of reception of atmospherics is reviewed in the next section of this report.

* The references are to the short bibliography appended to this report.

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II.—Historical.

In 1910, Eccles and Morris-Airey[4] made simultaneous graphic records of atmospherics in London and Newcastle. The general result of a long series of observations was that about 70 per cent. of the atmospherics heard at Newcastle had the same origin and were of about the same intensity as the corresponding ones heard in London, from which it followed that their sources were at distances great compared with the distance (430 km.) between the two stations. Mosler[5] observing in Germany in 1911-12 concluded that the disturbances caused by lightning discharges had no influence upon the receiving set at a distance of 200 km. from the storm centre. Flajolet[6] reported the recording of atmospherics from thunderstorms 500 km. distant. Eccles[7] from observations on the twilight minima of atmospheric disturbance, and particularly[8] from observations during the solar eclipse of April 17th, 1912, deduced that the principal source of the atmospherics received in London lay in Western Africa. Again, from simultaneous observations of atmospherics in England and of lightning in the Transvaal, Eccles[8] concluded that the Transvaal was a contributory but not a main source of the atmospherics heard in England. De Groot[9] observing in the Dutch East Indies concluded that the sharply defined type of atmospherics, classified as clicks, originated in lightning discharges, and had a range certainly less than 900 km. Goldschmidt[10] observing in the Belgian Congo, 1915-17, concluded that atmospherics from lightning had an effective range not exceeding 100 or 200 km., and reported that no simultaneous atmospherics were heard at three stations 1000 km. apart. Bellescize[11] on a review of the evidence available in 1925 takes it as established that the range of atmospherics from lightning is at the most a few hundred kilometres. He says:—"Jamais d'ailleurs, un orage local ne trouble sérieusement la réception d'un [puissant] émetteur [également éloigné, et] distant de quelques centaines de kilomètres seulement; c'est la preuve directe de l'infériorité relative des décharges atmosphériques. Il est également bien connu qu'en déplaçant quelque peu la situation d'un récepteur, on obtient parfois des résultats nettement différents.

"Le simple bon sens indique donc que les parasites susceptibles de brouiller un signal d'intensité courante doivent prendre naissance dans une zône assez rapprochée du lieu où se fait l'écoute."

On the other hand, Cave and Watson Watt[12] cited a case in which the bearing of a thunderstorm occurring at Venice was reported by two British direction-finding stations, one of which was at a distance of 1600 km. from the storm.

From similar data supplied by short wave direction-finding stations, Watson Watt[13] has given examples of cases in which thunderstorms have been located by radiotelegraphic position finding at distances reaching 2000 km.

Watson Watt[14] has further shown from automatic records of the direction of arrival of atmospherics using an apparatus tuned to the very long wave of 20,000 metres, that atmospherics radiated from a cold front could be traced in close relation to the front from a position off the Hebrides in the middle of one afternoon to the Rumanian Coast of the Black Sea 40 hours later. He has cited another location from the same instruments of a cold front in the

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region between Sardinia and Sicily.[15] In both cases the distance from the source to the most distant recording station was about 2500 km.

It has been objected[11 16] to these radiotelegraphic locations that the method used did not in fact give the direction of arrival of atmospherics proceeding directly from the source located, but merely measured the normal to a sort of "iso-parasitic" distribution around the apparent source. This objection appears to the Committee to substitute for a perfectly reasonable and straightforward acceptance of the known data as to the electrical quantities involved in the lightning discharge, a very complicated mechanism, invoked for the sole purpose of reconciling the direction finding results with a hypothesis that the ranges obtained are impossible. On this point the evidence on the nature of atmospherics obtained by Appleton, Watt and Herd,[17 18 19] is of fundamental importance. They have shown[19] that their measurement on the magnitude and duration of individual atmospherics fit well with C. T. R. Wilson's[20 21] determinations of the electric field changes produced by lightning discharges and that such discharges are capable of producing, at distances over 3000 km. from the source, radiation fields similar in magnitude to the average atmospheric recorded in this country.

Bureau[22] quotes evidence from which he deduces a limiting range of 40 km. for the atmospherics radiated from a particular cold front, and in general assigns limits of a very few hundred kilometres to the reception range of the atmospherics investigated by his methods.

Bäumler,[23 24] by recording the atmospherics received along with commercial radiotelegraphic signals, concludes that a large number of atmospherics recorded at a station in California were also recorded in the Hawaiian Islands, 4000 km. distant, and that occasional disturbances occur simultaneously at distances of 10,000 to 12,000 km.

It is not at present possible to effect any complete reconciliation of these very divergent estimates. Bäumler's results are open to the objection that on such a long base line as was used by him, without intermediate recording stations, there is a probability [*cf.* Austin[25]] that two completely independent atmospherics may be recorded at the two ends of the base within the accuracy of time-scale adopted. His methods would be much increased in value were they applied over a large and well distributed network of recording stations.

The objections to the direction finding methods on which Watson Watt's conclusions are based do not apply to the method of direction finding on individual atmospherics, described by Watson Watt and Herd.[26] This method so far as it has been tested supports the interpretations placed on the data from the automatic recorders. A special hypothesis has been tried to account for the difference between the results from the automatic recorders and those from the aural observations of interference with traffic reception on which Bureau's conclusions are based. This hypothesis is that an automatic recorder is almost exclusively a click recorder, while it is generally agreed that the type of atmospheric which most seriously interferes with reception is the grinder;

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thus it might be concluded that the long ranges are peculiar to clicks, while the short ranges are characteristic of grinders. The hypothesis, however, is rendered untenable by a large mass of auxiliary data. Thus Watson Watt's short wave data were based on observations made by stations and operators continuously engaged on traffic handling. It is therefore most probable that the atmospherics located in this series of observations were of the type which most interfere with traffic, and ought therefore to be comparable with those observed by Bureau's station. Moreover the grinder is a much more suitable subject for aural direction-finding than is the click. Again, both Bureau and Watson Watt have published data of the diurnal variations of the intensity of disturbance revealed by their methods, and it will be seen from the published data,[15 16] that the winter variation shown by the automatic recorder is Bureau's type I., while that of summer is of his type I. with a superposition of his type II. in daylight hours. Thus in respect of diurnal variation, the difference of character indicated in the estimated ranges is not reproduced. The Marconi Research staff[27] and the American Telephone and Telegraph Co.'s staff,[28] have also published data based on very extensive observations, and have concluded that the interferent atmospherics received in temperate latitudes are tropical or semi-tropical in origin, and have ranges of several thousands of kilometres. Nakagami and Kaneko[29] from directional observations at Osaka and Peking place the source of atmospherics there observed in the tropical Dutch Indies.

III.—Scheme of Observations.

The Committee decided that a special series of observations should be inaugurated with a view to throwing further light on the effective range of reception of atmospherics in normal receivers.

A scheme which had already been tried in Australia,[30] although apparently with disappointing results, seemed admirably suited for British conditions. The essence of its application to the end in view was that it enabled use to be made of a large body of skilled and enthusiastic amateur collaborators, and that it provided means for surmounting the extreme difficulties in synchronization which usually arise when simultaneous observations are required over wide areas, at stations without the equipment of astronomical observatories. The scheme was based on the use of the individual syllables of a broadcast talk as time marks to which could be referred the time incidence of individual atmospheric disturbances. By the kind co-operation of the British Broadcasting Company, manifold copies of the talks to be broadcast on specific dates were made available for circulation some days in advance, so that at the actual time of delivery of the talk, observers had before them a typescript copy. On this copy they marked the syllables mutilated by atmospherics as the talk was given, indicating the relative intensity of the atmospheric by the number of lines drawn through it; the duration of disturbance was recorded by making these lines begin and end on the syllables on which audible disturbance began and ended. Disturbances falling between words were indicated by crosses, of size proportioned to the intensity, in the appropriate spaces.

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The response to the circular calling for volunteers allowed of the formation of a cadre of observers, not numerous but well distributed, for the first observations. The observers numbered 1 to 21 in Table I. participated, with a few exceptions, in observations during ten-minute periods on dates between July 2nd and September 24th. The results obtained in this series of observations were so definite that it was decided to extend the area covered by the observing network; and observers at greater distances, and in regions not well represented in the original network, were invited to collaborate. The result of this invitation is shown in the portion of Table I. comprising observers Nos. 22 to 48. The augmented network made observations on ten occasions between October 8th and December 23rd, 1926.

The observations were suspended on the latter date in order to enable the Committee to make that full examination of the resulting data which forms the main object of this report.

IV.—Period of Observations.

The typescript circulated to observers usually covered two foolscap pages only, as this was considered to be the limit for close concentration and complete reduction. The matter contained in these two pages contained on the average some two thousand syllables. The average time for the delivery of these two thousand syllables was ten minutes. The dates and times of observations will be found in Table III.

V.—Reduction of Data.

The marked copies of the typescript were forwarded to a reducing centre where semi-graphic tables were compiled showing the cases in which any particular syllable was disturbed at any station. Summary tabulations were then made showing (*a*) the number of occasions on which *n* observers reported disturbance of the same syllable, and (*b*) the number of occasions when *n* observers reported disturbance of the same syllable or of immediately adjacent syllables. As a result of the experience gained in the early tabulations a special convention was adopted as to spaces between words, namely, that where one observer reported disturbance on a word space adjacent to a syllable reported by another as disturbed such a case would be excluded from group (*a*), but that where two observers reported disturbances on two different syllables separated by a word space, such a case would still be admitted to group (*b*). Any convention of this kind is necessarily arbitrary, but it was felt to be a suitable compromise allowing the maintenance of rigid synchronism in group (*a*) without allowing too wide a tolerance in group (*b*), since, in fact, a word space does not, on the average, occupy the same time interval as does a normal syllable. The two groups (*a*) and (*b*) thus formed may be regarded, then, as groups for (*a*) observations giving complete simultaneity without adjustment, and (*b*) observations in which one time unit tolerance is allowed for adjustment of personal error. The value of the syllabic time unit is approximately 0.3 of a second. Anyone who has made observations of this character will agree that even this tolerance is a stringent one, and will appreciate the very high quality of the observers' work appearing from the examination that follows.

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There was then prepared, for each time of observation, a contingency table showing the number of occasions on which each combination of two individual stations recorded simultaneous disturbance, the standard of simultaneity being that of group (*b*). It will be seen from Table I., which shows the mean number of atmospherics per period recorded by each observer, during the time November 3rd to December 23rd, when the majority of the observers were on watch, that there were wide divergences of site, set-sensitivity, and personal equation affecting the level of disturbance recorded by each observer. It was therefore necessary to make some attempt to reduce the effect of over-all sensitivity in masking the geographical differences which were being investigated. The method of weighting the data to compensate for set-sensitivity and personal equation was then that new contingency tables were drawn up in the following manner:—

a, *b*, *c*, *d*, etc., denote the individual observing stations and X_{ab}, X_{ac}, . . . denote, for instance, the numbers in cells *ab*, *ac* . . . and Y_{bc}, Y_{bd}, . . . in the same way denote the numbers in cells *bc*, *bd*, . . . as shown below:—

	a	*b*	*c*	*d*
a	y_a	X_{ab}	X_{ac}	X_{cd}
b	—	y_b	Y_{bc}	Y_{bd}
c	—	—	y_c	Z_{cd}
d	—	—	—	y_d
	N_a	N_b	N_c	N_d

where y_a, y_b, etc., represent the relative numbers of atmospherics unpaired, and N_a, N_b, etc., represent the total numbers of atmospherics observed by each observer in the period; X_{ab}, for example, $= 10^n \times$ (number of occasions on which *a* and *b* observed disturbance in the same or adjacent syllables) $\div$ (mean number of atmospherics observed by *a* $\times$ mean number observed by *b*, from Table I.). Also $y_a = 10^n \times$ (total number of atmospherics unpaired in *a*'s observations) $\div$ (mean number observed by *a* from Table I.),[2] *n* being chosen arbitrarily to clear of fractions (actually $n = 4$).

The order of rows and columns in the tables was also rearranged to bring the stations approximately into order of decreasing latitude, some divergence being allowed from a strict latitude sequence so that stations geographically near might be found in neighbouring rows and columns. Fig. 1 shows the situation of the observers, identified by their reference numbers as in Table I., these reference numbers being also used in the weighted and geographically arranged contingency tables which, for each separate period of observation, form Tables II.*a* to II.*q*, while the corresponding lumped tables for the earlier and later series are Tables II.*s* (July 2nd to September 24th inclusive), II.*w* (October 8th to December 23rd) and for the whole series II.*t*. The italic figures show the unweighted data, the ordinary figures show data weighted as above described.

It will be seen from the manner of arrangement that the limiting diagonal of each table is formed by cells containing the numbers of "unpaired" atmospherics observed solely by the observer in whose row and column the cell appears. The cells adjacent to the

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limiting diagonal deal with atmospherics observed simultaneously at geographically adjacent stations. If, then, any notable percentage of the disturbing atmospherics were received only at short ranges, the general aspect of the table would be that of a collection of numbers which decreased progressively as they receded from the limiting diagonal.

The Committee is unable to trace any such tendency in any one of the tables, and concludes that no considerable proportion of the atmospherics disturbing broadcast reception on the evenings investigated, evenings distributed at random throughout half a year, were of such character as to be received only at short ranges. Indeed, they interpret the evidence set out in full in these tables,

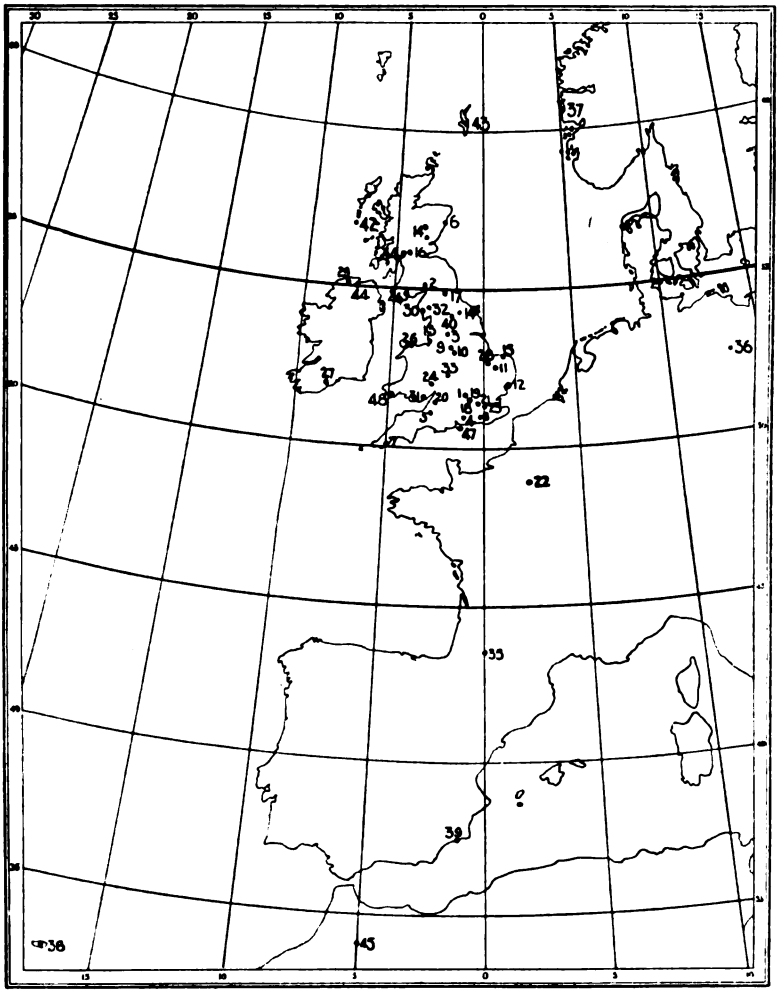

FIG. 1.
Positions of Observers.
(Identification numbers as in Table I.)

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as showing that the average range of reception, on normal broadcast receivers, on wave lengths of 350 to 400 and of 1600 metres, of the great majority of disturbing atmospherics, is not less than half the distance between the extreme stations of the network. The lower limit of normal range thus assigned is 1750 km. or 1000 miles.

It is admitted that the method of weighting adopted is not entirely satisfactory, as is seen from the following argument. Let *A*, *B* and *C* be adjacent observers, *A* with a sensitive set, *B* with an insensitive set. Then if *C* have an insensitive set, it is to be expected that he will "pair" the same atmospherics with both *A* and *B*, but if he have a sensitive set he will "pair" strong atmospherics with both *A* and *B*, but weak atmospherics with *A* alone. Now the method of weighting adopted involves the assumption that the pairings of *A* and *C* are uniformly distributed between the atmospherics paired between *A* and *B* and those not so paired. It appears probable, therefore, that the method will result in excessive weighting. But it will be seen that the contingency tables lead to the same conclusions whether the unweighted or the over-weighted figures be examined, so that the conclusions are not vitiated by the inability to find a logical weighting system capable of application without prohibitive labour.

VI.—Sources of Atmospherics.

In the foregoing tables, evidence has been obtained that the atmospherics producing interference during certain broadcast talks have a very considerable range. It is now proposed to indicate some of the probable actual sources of these atmospherics. Further, while it is not intended in the present report to devote much attention to the relation between atmospherics and weather, yet some brief notes will be given on the meteorological conditions in the vicinity of the suggested sources.

The material immediately available consists of:—

(1) Fixes of sources of atmospherics obtained by means of automatic directional recorders at Lerwick (Shetland), Ditton Park (Bucks) and Aboukir (near Alexandria, Egypt). Reference (13).

(2) Eye readings of the directions of arrival of atmospherics at Ditton Park (Bucks), obtained by means of a cathode-ray direction-finder. Reference (22).

(3) The working charts of the Forecast Division, Meteorological Office, Air Ministry, for the days concerned. These charts show the general distribution of meteorological conditions over an area extending from Spitzbergen in the North to Algeria in the South, and from mid-Atlantic to Egypt and the Urals, being based solely on data received by W/T in the course of the ordinary daily international exchange. From the present point of view there are large gaps in the réseau of stations, and in the later stages of the work steps will be taken to provide a closer network.

The method of obtaining fixes for the location of apparent sources of atmospherics can be followed by reference to the paper[13]

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cited above, the intersections of bearings obtained by examination of the autographic records being obtained by examination of a gnomonic chart of the world approximately centred on Ditton Park, on which have been plotted in distinctive colours iso-azimuthal graticules referred to the other recording stations. In some cases double or multiple atmospheric distributions can be resolved and simultaneous sources plotted.

The observations made with the cathode-ray direction-finder at Ditton Park enable the direction of arrival of individual atmospherics to be specified. Arrangements were made for special observations of atmospheric wave-forms and directions of arrival during the periods of the present experiments, the times of incidence of the observed atmospherics being referred directly to the time marks constituted by the broadcast syllables. The wave-form data are not discussed in the present paper, but it will be seen in later paragraphs that the directional observations enable an almost certain specification to be made of the place of origin of individual atmospherics recorded as producing disturbance at various stations, thus giving a very sound foundation for lower limiting estimates of reception range.

Table III. which is given below indicates the following:—

Column 1.—Date and time of the broadcast talk.

Column 2.—Positions of the automatic fixes at the hours before and after the broadcast talk. The figures denote the hours, and the letters D, A and L, respectively, denote the stations used in determining the fixes given. Then follow the latitude and longitude of the fixes, with a verbal indication of the region where they fall.

Column 3.—Similar data to those given in column 2, for the two hours preceding and the two hours following those given in column 2.

Column 4.—The bearing from Ditton Park of the fixes given in column 2. When two figures are given in the same line they refer to the two hours in column 2, respectively. Figures given in separate lines refer to different fixes.

Column 5.—The directions given by the cathode ray indicator, which approximate closely to the directions in column 4. This column does not necessarily indicate all or even the most frequent of the directions given by the cathode-ray direction-finder, but only those which agree with column 4. The agreement between columns 4 and 5 shows that some considerable part, at any rate, of the atmospherics which disturbed the broadcast talks originated in directions agreeing with those of the fixes in column 2.

Column 6.—The weather in the region of the fixes given in column 2, where details are available.

Column 7.—A "disturbance index" number giving an approximation to the relative number of atmospherics recorded per unit time by observers, referred to the most disturbed evenings, which are given the index number 100. It was at first proposed to give index numbers for three geographical regions, but as will be seen from the tables there is no definite evidence of differences from region to

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region; in general it is quite clear that the disturbance index varies similarly over the whole area explored.

Column 8.—Notes from contingency tables. Here are shown, on a uniform system, typical extracts from the contingency tables showing the extent to which disturbance is common to widely separated stations. In order to have a method of presentation which is independent of the weighting system already discussed, the notes show, for the pairs of stations named, first the total number of atmospherics observed during the observation period in question at the first named station, then the number observed at the second station, and thirdly the number of atmospherics observed simultaneously at both stations.

In extracting the fixes of column 2 from the working tables, when possible, three-point fixes only were used, and only on days when one of the three stations was not working were two-point fixes taken. It may be remarked that any one of the three automatic recording stations may, over the interval of one hour for which readings were used, give more than one direction, and two directions of sources are frequently indicated. The use of all the directions given at the three stations may thus give more than one three-point fix in column 2 of our table for any one hour of observation. When such is the case, it is possible, by taking all the possible combinations of two stations, to obtain a number of two-point fixes also. In the present investigation, however, we have adopted the definite plan of leaving out of consideration any two-point fixes when three-point fixes are available. In the case of three-point fixes it should be noted that in the determination of the positions of both two- and three-point fixes there is a mathematical ambiguity, since the direction-finders do not show the sense of the direction of arrival and since any number of great circles on the earth surface passing through one point also pass through the point diametrically opposite. The position of the opposite point is obtained by reversing the sign of the latitude and adding 180° to the assigned longitude. In most of the cases indicated in column 2, however, there is little doubt that the correct fix has been taken.

The examination of column 6 is of interest. In cases where no fixes are given in column 2, column 6 is left blank. In a number of other cases no details can be given as the fixes fall outside the area of the weather charts available. The cases of October 27th may be noted. The three automatic recording stations give a good determination of the position of a source in about 30° N. 30° W. over the Atlantic, and the 18h. chart shows a well marked cold front running N.E. to S.W., passing through the Azores at approximately 18h. There are other cases where the fixes given by the automatic recording instruments agree with the positions of regions of thunderstorm activity. For example, on November 10th, coastal thunderstorms occurred along the coast of Portugal, due to the arrival of a current of air whose earlier history can readily be traced back to a position south of Greenland some 36 hours previously. It will be seen that columns 2 and 3 indicate sources of atmospherics along the coast of Portugal during a period of at least six hours.

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We are thus in a position to say that, in some cases at least, the atmospherics which gave interference during the talk originated at clearly defined cold fronts, or in regions of thunderstorm activity. Further, on one occasion, December 16th, 1926, the interference with the broadcasting was very slight, the atmospherics probably originating at an occluded depression south-east of Archangel. In general it may be said that the disturbance index of column 7 is in close agreement with the available data as to the distance and probable vigour of the sources independently located by position finding.

The case of December 23rd is of particular interest from the point of view of the location of cold fronts by radiotelegraphic position finding. A cold front was on that evening in a position running southward from 65°N., 45° E., through 60° N., 40° E. The radiotelegraphic data was reported, by an examiner in complete ignorance of the meteorological data, to indicate an elongated source from 65° N., 40° E., to 50° N., 40° E.

VII.—Diary of Observations.

It may be of interest to give a diary of the observation periods in which are summarized briefly the character of the disturbance reported by observers, the probable sources of the disturbance, with an indication of the degree of probability, and specimens of the grouping of stations disturbed by individual atmospherics identified as proceeding from a given source.

July 2nd.—Observers too few for useful examination.

July 9th.—Atmospherics numerous, of a uniform short sharp character, but not violent. Thunderstorms along east coast of England at time of observation, unfavourably distributed for location by recorders. More distant locations not discussed in view of local disturbance. Disturbance at Falmouth, Oxford, Streatley-on-Thames and Windsor, outside thunderstorm zone, comparable with that at Huddersfield and Holt (Norfolk) in the zone.

July 16th.—Continuous background of weak atmospherics. Cold front moving south over central Europe, with thunderstorms there, located by morning and afternoon records but no certain evening locations there.

July 23rd.—Generally quiet, but with a continuous weak background disturbing more sensitive sets. Location of source not verifiable by available meteorological data.

Aug. 13th.—Continuous crackling "frying" disturbance, without sharply marked individuals standing out. No evening locations obtained.

Sept. 17th.—Very quiet. Location not verifiable at present.

Sept. 24th.—Continuous but weak disturbances. No locations obtained near time of observation.

Oct. 8th.—Continuous disturbance, not improbably proceeding from a source in Algeria. Atmospherics from this direction were observed simultaneously, one at Oxford, Windsor, Darlington and Eskdalemuir, and another at Falmouth,

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Horeham Road (Sussex), Wallingford-on-Thames, Windsor, Felixstowe, Darlington, Eskdalemuir and Aberdeen. Probable range thus exceeds 2500 km. (1500 miles).

Oct. 15th.—Extremely quiet. Signals from London and abroad very weak, probably on account of magnetic storm. No near source located. The reduction of received disturbance on short wave lengths as a result of magnetic storm must not be excluded as a possible explanation of the exceptional quiet.

Oct. 27th.—Average disturbance. Aberdeen, Darlington and Cork agree in reporting atmospherics to be exceptionally clearly defined, as "single cracks," etc. Aguilas (Spain) reports disturbance of crashing or grinding character with notable absence of "frying" and "machine gun" types.

Almost certain location of source in Atlantic, south of Azores. Atmospherics from this source were observed simultaneously at Paris, Cork, Bath, Streatley-on-Thames, Wallingford-on-Thames, Oxford, Windsor, London, Horeham Road (Sussex), Bury St. Edmunds, Holt (Norfolk), Darlington, Earlston (Berwickshire), Aberdeen, and again at Aguilas, Paris, Darlington, Conway, Cork; and at Paris, Oxford, Wallingford, Bury St. Edmunds, Donegal and Aberdeen. Probable range thus exceeds 3700 km. (2300 miles).

A still more important source bearing 190° from Ditton Park has not yet been identified. It gave disturbances heard simultaneously at Cork, Street (Somerset), Bath, Oxford, Wallingford, Streatley, Windsor, London, Horeham Road, Paris, Aguilas, Bury St. Edmunds, Norfolk, Matlock, Darlington, Conway, Donegal, Glasgow, Berwickshire, Aberdeen, and again at Cork, Bath, Oxford, Wallingford, Streatley, Windsor, London, Paris, Aguilas, Bury St. Edmunds, Norfolk, Eskdalemuir and Aberdeen.

Nov. 3rd.—Very severe disturbance generally; completely preventing observation at Funchal (Madeira), continuous grinders at Potsdam, constant frying at Aguilas (Spain).

Sources over southern France, thunderstorms in Marseilles region. Majority of atmospherics observed in Spain and Pyrenees and at Potsdam, also observed at Windsor. Fifty per cent. of Pyrenees atmospherics observed at Bergen (Norway).

Nov. 10th.—Rather bad disturbance generally, very bad in Spain and Morocco, prohibitive at Paris and Madeira. Main disturbance proceeding from cold front near Portuguese coast. Lightning at Falmouth and Bury St. Edmunds, thunderstorm at Fez throughout period. Atmospheric electric conditions prevented observation by waveform apparatus. Several cases of disturbance by the same atmospheric at 18 to 20 of the 32 stations observing.

Nov. 18th.—Atmospherics numerous but not strong. Practically certain identification of two sources, one over

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Italy (confirmed by report of thunderstorm at Rome 18h.), one over Bay of Biscay. Atmospherics from source near Rome were heard simultaneously at Aguilas (Spain), Pyrenees, Paris, Windsor, Bergen (Norway); again at Aguilas, Falmouth, Windsor, Darlington, Donegal, Bergen; Pyrenees, Falmouth, Bergen; Paris, Falmouth, Bergen; Paris, Falmouth, Donegal; Aguilas, Donegal, Funchal (Madeira); Aguilas, Pyrenees, Bath; Funchal, Aguilas, Pyrenees, London, Horeham Road (Sussex); Windsor, Streatley-on-Thames, Wallingford-on-Thames, Bath, Bury St. Edmunds, Darlington, Conway, Cork, Donegal, Bergen; Funchal, Aguilas, Pyrenees, Paris, Windsor, Falmouth, Darlington, Donegal, Bergen, etc.; Aguilas, Pyrenees, Windsor, Falmouth, Glasgow, Donegal; Funchal, Pyrenees, Windsor, Donegal, Bergen, Pyrenees, Windsor, Bath; Pyrenees, Funchal, Bergen; Murcia, London, Wallingford, Hereford, Conway, Donegal, Belper, Darlington, Glasgow; and Pyrenees, Windsor, Streatley, Falmouth, Conway and Bergen. Atmospherics from the source in the Bay were heard simultaneously at Donegal and Pyrenees; Falmouth, Windsor and Bergen; Donegal and Pyrenees; Pyrenees, Aguilas, Oxford and Bergen; Funchal, Aguilas, Falmouth and London; Pyrenees, Falmouth and Cork; and Funchal, Aguilas, Falmouth, Horeham Road (Sussex), Streatley, Windsor, Bury St. Edmunds, Conway and Bergen.

Probable ranges thus greater than 2900 km. (1800 miles) and 1750 km. (1100 miles).

Nov. 25th.—Conditions relatively quiet. Main source, bearing 130° from Ditton Park not yet identified. Source of less intense disturbance in Atlantic doldrums, whence atmospherics were heard at Fez (Morocco), Aguilas (Spain), Donegal, Conway and Oxford; at Donegal, Aberdeen, St. Bees (Cumberland), Coventry, Conway, Hereford, Bath, Windsor, Isle of Wight; at Bergen; at Falmouth; and at Bergen and Falmouth. The relative smallness of these groups corresponds to the small amplitude of the disturbances. Probable range thus greater than 7000 km. (4500 miles).

The unidentified source gave simultaneous disturbance at Funchal, Fez, Aguilas, Potsdam, Wallingford, Windsor, Bath, Hereford, Conway, St. Bees, Londonderry; at Aguilas, Potsdam, Cowes, Pembroke, Conway, Bath, Wallingford, Darlington, Bergen; at Fez, Aguilas, Potsdam, Norfolk, St. Bees, Conway, Cork, Bergen; at Bergen; and at Potsdam, Aberdeen, Norfolk, Belper, Wallingford and Falmouth.

Dec. 9th.—Weak disturbance on this date probably proceeded from a cold front between Crete and Egypt, whence simultaneous disturbance was recorded at Aguilas (Spain), Potsdam, Paris, London, Cowes, Hereford, Cork, Donegal, Bury St. Edmunds, Huddersfield, Berwickshire,

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Lerwick; Horeham Road (Sussex), Windsor, Lerwick; Aguilas, Potsdam, Paris, London, Windsor, Streatley, Wallingford, Oxford, Horeham Road, Cowes, Street (Somerset), Bath, Cardiff, Pembroke, Cork, Donegal, Lerwick, Darlington, Huddersfield, Coventry, Bury St. Edmunds. Probable range thus greater than 3400 km. (2100 miles).

Dec. 16th.—Remarkably quiet. Of 36 observers 21 returned reports of no disturbance whatever. Aguilas (Spain) remarked that this was the only evening in three years which was without grinding and frying disturbance. Fez (Morocco) reported particularly quiet conditions, remaining so on 360 metres throughout evening, but with increasing disturbance on 1600 metres. Bergen (Norway) reported a day of very little disturbance. Potsdam (Germany) reported no disturbance on Aberdeen's wave length, and could be sure of one only of four atmospherics reported on Daventry.

Dec. 23rd.—Conditions had become normal as regards disturbance level. Principal sources were located on cold fronts, one near Archangel, one between Sardinia and Algeria. Atmospherics from the Mediterranean front were received simultaneously at Cowes, Street (Somerset), Cork, Pembroke, Conway, Streatley, Belper, Bury St. Edmunds, Darlington, Berwickshire and Eskdalemuir; at Potsdam, Paris, Pembroke, Cork, Donegal; at Cork, Pembroke, Street, Cowes, Streatley, Darlington; and at Paris, Potsdam, Cowes, Wallingford, Oxford, Bath, Conway, Cork, Darlington. Probable range thus greater than 2000 km. (1250 miles).

It should be added that in no case was a class *b* tolerance in timing accepted in the groupings of this diary, the disturbance was strictly simultaneous at all stations within the limits of one syllable plus one word space, *i.e.*, the tolerance in time was less than half a second.

VIII.—Special Details.

There remain for discussion only a group of minor details emerging from the analysis of the observers' returns, but the details are of singular interest as indices of the remarkable quality of the observational work carried out by the Committee's collaborators, and also as confirmatory evidence of the reception ranges inferred. These details comprise the occasions when groups of stations agreed not merely as to the temporal incidence of individual disturbances, but also as to their characteristics. It was noted in section III. that observers were invited to indicate the relative strength of disturbances by a special code of markings. When this code was suggested it was recognized that the problem posed was one of extreme difficulty, and it is therefore the more gratifying that a number of observers succeeded in making records of such character that the intensity data could be utilized. Table IV. (*a*) contains a list of the cases in which two or more observers, indicated

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by their reference numbers, marked the same atmospheric as being especially strong. Table IV. (*b*) similarly contains the cases in which observers reported two disturbances within the same word space. It will be realized that these agreements greatly reinforce confidence in the essential identity of the phenomena recorded simultaneously at different stations.

Perhaps the prettiest case of strength characterization is that in which on November 18th, Aguilas (Spain) and Darlington (1900 km. or 1200 miles apart) observed disturbance on the two successive words "for his." Both marked the word "for" as heavily disturbed, the word "his" as lightly disturbed only. Bury St. Edmunds agreed as to the specially heavy disturbance on "for," but missed the lighter disturbance on "his." Windsor reported disturbance above average strength on both words.

The frequency with which such pairs as Madeira-Norway (3500 km.), Spain-Norway (2600 km.) and Germany-Ireland (1450 km.) appear in Tables (*a*) and (*b*) is, as has been remarked, very strong confirmatory evidence as to the effective reception range, and emphasizes the fact that the estimates given are lower limits only, since they represent cases in which the atmospheric is still, at each station, very far indeed from the limit of attenuation at which it will reach inaudibility.

A particularly pleasing example from Table IV. (*b*) is the first of October 27th, when Bath alone reported a double interference in a particular word space. This was completely confirmed by the cathode-ray direction-finder at Ditton Park which showed two atmospherics arriving within a small fraction of a second, one of large amplitude from 210°, one slightly smaller from 190°.

Incidental evidence is also obtainable from the observations on a point frequently overlooked by designers of devices for the mitigation of atmospheric interference. This is that although the unitary impulses constituting the disturbance have a duration of the order of a thousandth of a second only, yet they are discharged in streams which may last for a time of the order of seconds. Thus, for example, the observers in Madeira, Spain, Cork, Bury St. Edmunds and Darlington all recorded continuous disturbance over the phrase "and light and aspect of the features," *i.e.*, over approximately three seconds. They were supported by Pyrenees, Windsor and Falmouth, who showed only slight gaps in this disturbance.

It will be seen from Table I. that the observations were made on London, Daventry, Bournemouth and other stations. Despite the difference in wave length between the 350-400 metre band and Daventry's 1600 metre wave, pairings between London and Daventry records are no less frequent than between London-London and Daventry-Daventry records. Nor were Daventry pairings notably more or less numerous than were short-wave pairings. In sum, no important wave length effect reveals itself in the data. It will be seen that the method does not lend itself to the determination of the mean intensity of disturbance as opposed to the identification of individual impulses. There can be no doubt that on the mean, and *ceteris paribus*, the Daventry wave length is more disturbed than are the shorter wave lengths.

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Lerwick; Horeham Road (Susse ENTS.
Aguilas, Potsdam, Paris, Lond idence set forth in
Wallingford, Oxford, Horeha
(Somerset), Bath, Cardiff, P
Lerwick, Darlington, Hudde of very many atmos-
Edmunds. Probable range ast receivers, exceeds
(2100 miles). es at least 7000 km. or

Dec. 16th.—Remarkably quiet
reports of no disturba presence of many atmos-
remarked that this was than 200 km.; that such
which was without gri st, never formed so much as
(Morocco) reported pa tion on any of the occasions
so on 360 metres thr
disturbance on 160 ained confirms previous experi-
a day of very l fronts are of great importance
reported no distu mospheric disturbance.
could be sure of andom samples here considered
on Daventry. tion of the meteorological environ-

Dec. 23rd.—Condit
ance level. P knowledgments and thanks to many
one near Ar success of this preliminary investiga-
Atmospheri ank their collaborators the observers,
simultaneo programme and whose extraordinarily
broke, C ational accuracy produced data of great
Darlingto they would thank the British Broad-
Paris, I and its staff, particularly in the engineering
Street, ments, with special thanks to Captain
dam, Miss M.A., B.Sc., without whose encouragements the
Darlir would not have been begun, and without whose con-
(125C it could not have been completed. They would thank
tole of Scientific and Industrial Research which, on the
the ion of its Radio Research Board, placed at its disposal
w ation available at Radio Research Station, Ditton Park,
t which gave facilities for some of the clerical and computing
work of the investigation. They would thank the staff of Radio
Research Station for their assistance. The Director of the Meteoro-
logical Office kindly allowed the Committee to make use of the
Th forecasting charts referred to in Section VI. Mr. S. Morris Bower
emergi rendered valuable assistance in the extension of the network. The
details Council of the Society made a grant from the Research Fund to
of the cover the expenses of the investigation. And finally the Com-
tors, mittee would tender its apologies and thanks to the broadcasting
infer speakers who provided, albeit involuntarily, the time scales for the
stat experiments.
dis' *In furtherance of conclusion (d) of Section IX., the Committee*
sec *proposes that application should be made to all the meteorological*
st services of the world for the fullest possible data of thunderstorm
c disturbance on the seventeen dates of the observations discussed in
o this report. It hopes to compile from this information thunderstorm
t charts for the whole world, on which to base a subsequent detailed
report on the connection between the atmospheric disturbance of
the dates in question and the world meteorological situation on
these dates.

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...IONS RECEIVED AND MEAN NUMBER OF ...N NOV. 3RD AND DEC. 21ST, 1926.

		Address.	Station received.	Mean No. of X's heard.
		Oxford.	L.	13.6
		Eskdalemuir, Dumfries.	L.	5.2
		Huddersfield.	L.	15.2
		Petersfield.	L.	12.5
		Street, Somerset.	D.	10.0
		Aberdeen.	L.	58.0
		Falmouth.	D.	90.3
		Horeham Road, Sussex.	L.	22.3
	...hapman.	Matlock.	L.	10.5
		Belper.	L.	22.8
	...kton.	Bury St. Edmunds.	L. & D.	35.9
	...ring.	Felixstowe.	L.	2.5
	...mery.	Blundellsands.	L.	—
	...use.	Darlington.	L.	23.3
	"	Pitlochry.	L. & D.	45.7
	... St. L. Simon, C.B.E.	Holt, Norfolk.	L.	14.0
	...A. M. Scott.	Glasgow.	L.	8.8
	... D. Simpson.	Earlston, Berwickshire.	L.	31.5
	...jor H. A. P. Littledale.	Streatley.	L.	25.6
	... Walker.	Crowmarsh, near Wallingford, Berks.	B. & N.	27.7
	W. Blathwayt.	Bath, Somerset.	D.	26.6
	J. E. Airey.	Wraysbury, near Windsor, Berks.	L.	59.9
	Capt. R. Bureau.	Paris.	D.	29.8
	Dr. L. Trotter.	Ledbury, Herefordshire.	D.	53.7
25	D. Trevelyan.	Kew, Surrey.	D. & L.	19.1
26	A. Wilson.	Conway.	D.	41.0
27	J. Mintern.	Cork.	D.	33.7
28	F. C. L. Richardson.	Over, Cambs.	D.	10.3
29	Rev. W. J. Young.	Milford, Tir Chonaill, I.F.S.	D.	50.6
30	G. A. L. Helder.	St. Bees, Cumberland.	D.	52.5
31	W. J. B. Rees.	Near Cardiff.	D.	7.0
32	Miss Ann Macbeth.	Penrith.	L.	10.0
33	A. Feast.	Coventry.	D.	5.3
34	T. White.	Paisley, Renfrewshire.	D.	29.0
35	M. C. Dauzère.	Hautes Pyrenees, France.	D.	53.7
36	Dr. F. Schindelhauer.	Potsdam, Germany.	D.	38.0
37	Dr. J. Bjerknes.	Bergen, Norway.	D.	58.0
38	F. C. Walker.	Funchal.	D.	41.0
39	G. L. Boag.	Murcia, Spain.	B. & D.	38.7
40	Rev. R. C. Owen.	Richmond, Yorks.	D.	1.0
42	K. Macleod.	Castlebay, Barra.	D.	6.3
43	G. W. Manson.	Lerwick, Shetland.	D.	38.8
44	A. Robinson.	Londonderry.	D.	18.0
45	Gilbert Mackereth.	Fez, Morocco.	B. & D.	19.3
46	W. J. Hale.	Newton Stewart, Wigtownshire.	D.	25.0
47	R. S. Bailey.	East Cowes.	D.	18.8
48	H. I. Jackson.	Pembroke.	D.	23.0

D=Daventry 1600 metres. L=London 365 metres. B=Bournemouth 386 metres. N=Newcastle 410 metres.

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Lerwick; Horeham Road (Sussex), Windsor, Lerwick; Aguilas, Potsdam, Paris, London, Windsor, Streatley, Wallingford, Oxford, Horeham Road, Cowes, Street (Somerset), Bath, Cardiff, Pembroke, Cork, Donegal, Lerwick, Darlington, Huddersfield, Coventry, Bury St. Edmunds. Probable range thus greater than 3400 km. (2100 miles).

Dec. 16th.—Remarkably quiet. Of 36 observers 21 returned reports of no disturbance whatever. Aguilas (Spain) remarked that this was the only evening in three years which was without grinding and frying disturbance. Fez (Morocco) reported particularly quiet conditions, remaining so on 360 metres throughout evening, but with increasing disturbance on 1600 metres. Bergen (Norway) reported a day of very little disturbance. Potsdam (Germany) reported no disturbance on Aberdeen's wave length, and could be sure of one only of four atmospherics reported on Daventry.

Dec. 23rd.—Conditions had become normal as regards disturbance level. Principal sources were located on cold fronts, one near Archangel, one between Sardinia and Algeria. Atmospherics from the Mediterranean front were received simultaneously at Cowes, Street (Somerset), Cork, Pembroke, Conway, Streatley, Belper, Bury St. Edmunds, Darlington, Berwickshire and Eskdalemuir; at Potsdam, Paris, Pembroke, Cork, Donegal; at Cork, Pembroke, Street, Cowes, Streatley, Darlington; and at Paris, Potsdam, Cowes, Wallingford, Oxford, Bath, Conway, Cork, Darlington. Probable range thus greater than 2000 km. (1250 miles).

It should be added that in no case was a class *b* tolerance in timing accepted in the groupings of this diary, the disturbance was strictly simultaneous at all stations within the limits of one syllable plus one word space, *i.e.*, the tolerance in time was less than half a second.

VIII.—Special Details.

There remain for discussion only a group of minor details emerging from the analysis of the observers' returns, but the details are of singular interest as indices of the remarkable quality of the observational work carried out by the Committee's collaborators, and also as confirmatory evidence of the reception ranges inferred. These details comprise the occasions when groups of stations agreed not merely as to the temporal incidence of individual disturbances, but also as to their characteristics. It was noted in section III. that observers were invited to indicate the relative strength of disturbances by a special code of markings. When this code was suggested it was recognized that the problem posed was one of extreme difficulty, and it is therefore the more gratifying that a number of observers succeeded in making records of such character that the intensity data could be utilized. Table IV. (*a*) contains a list of the cases in which two or more observers, indicated

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by their reference numbers, marked the same atmospheric as being especially strong. Table IV. (*b*) similarly contains the cases in which observers reported two disturbances within the same word space. It will be realized that these agreements greatly reinforce confidence in the essential identity of the phenomena recorded simultaneously at different stations.

Perhaps the prettiest case of strength characterization is that in which on November 18th, Aguilas (Spain) and Darlington (1900 km. or 1200 miles apart) observed disturbance on the two successive words "for his." Both marked the word "for" as heavily disturbed, the word "his" as lightly disturbed only. Bury St. Edmunds agreed as to the specially heavy disturbance on "for," but missed the lighter disturbance on "his." Windsor reported disturbance above average strength on both words.

The frequency with which such pairs as Madeira-Norway (3500 km.), Spain-Norway (2600 km.) and Germany-Ireland (1450 km.) appear in Tables (*a*) and (*b*) is, as has been remarked, very strong confirmatory evidence as to the effective reception range, and emphasizes the fact that the estimates given are lower limits only, since they represent cases in which the atmospheric is still, at each station, very far indeed from the limit of attenuation at which it will reach inaudibility.

A particularly pleasing example from Table IV. (*b*) is the first of October 27th, when Bath alone reported a double interference in a particular word space. This was completely confirmed by the cathode-ray direction-finder at Ditton Park which showed two atmospherics arriving within a small fraction of a second, one of large amplitude from 210°, one slightly smaller from 190°.

Incidental evidence is also obtainable from the observations on a point frequently overlooked by designers of devices for the mitigation of atmospheric interference. This is that although the unitary impulses constituting the disturbance have a duration of the order of a thousandth of a second only, yet they are discharged in streams which may last for a time of the order of seconds. Thus, for example, the observers in Madeira, Spain, Cork, Bury St. Edmunds and Darlington all recorded continuous disturbance over the phrase "and light and aspect of the features," *i.e.*, over approximately three seconds. They were supported by Pyrenees, Windsor and Falmouth, who showed only slight gaps in this disturbance.

It will be seen from Table I. that the observations were made on London, Daventry, Bournemouth and other stations. Despite the difference in wave length between the 350-400 metre band and Daventry's 1600 metre wave, pairings between London and Daventry records are no less frequent than between London-London and Daventry-Daventry records. Nor were Daventry pairings notably more or less numerous than were short-wave pairings. In sum, no important wave length effect reveals itself in the data. It will be seen that the method does not lend itself to the determination of the mean intensity of disturbance as opposed to the identification of individual impulses. There can be no doubt that on the mean, and *ceteris paribus*, the Daventry wave length is more disturbed than are the shorter wave lengths.

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IX.—Conclusions and Acknowledgments.

The Committee are of opinion that the evidence set forth in this report is conclusive in showing

(*a*) That the effective range of reception of very many atmospherics heard on normal broadcast receivers, exceeds 3000 km. or 1850 miles, and reaches at least 7000 km. or 4500 miles.

(*b*) That there is no evidence of the presence of many atmospherics whose range is less than 200 km.; that such atmospherics, should they exist, never formed so much as 25 per cent. of the distribution on any of the occasions discussed.

(*c*) That the evidence here obtained confirms previous experience in showing that cold fronts are of great importance in the origination of atmospheric disturbance.

(*d*) That the seventeen random samples here considered demand fuller examination of the meteorological environment.

The Committee owes acknowledgments and thanks to many who have contributed to the success of this preliminary investigation. First they would thank their collaborators the observers, whose fidelity to an exacting programme and whose extraordinarily high standard of observational accuracy produced data of great scientific value. Secondly, they would thank the British Broadcasting Corporation and its staff, particularly in the engineering and programme departments, with special thanks to Captain A. G. D. West, M.A., B.Sc., without whose encouragements the investigation would not have been begun, and without whose constant help it could not have been completed. They would thank the Department of Scientific and Industrial Research which, on the recommendation of its Radio Research Board, placed at its disposal the information available at Radio Research Station, Ditton Park, and which gave facilities for some of the clerical and computing work of the investigation. They would thank the staff of Radio Research Station for their assistance. The Director of the Meteorological Office kindly allowed the Committee to make use of the working charts referred to in Section VI. Mr. S. Morris Bower rendered valuable assistance in the extension of the network. The Council of the Society made a grant from the Research Fund to cover the expenses of the investigation. And finally the Committee would tender its apologies and thanks to the broadcasting speakers who provided, albeit involuntarily, the time scales for the experiments.

In furtherance of conclusion (*d*) of Section IX., the Committee proposes that application should be made to all the meteorological services of the world for the fullest possible data of thunderstorm disturbance on the seventeen dates of the observations discussed in this report. It hopes to compile from this information thunderstorm charts for the whole world, on which to base a subsequent detailed report on the connection between the atmospheric disturbance of the dates in question and the world meteorological situation on these dates.

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TABLE I.—List of Observers, with stations received and mean number of Atmospherics heard per period between Nov. 3rd and Dec. 21st, 1926.

Identification No.	Name.	Address.	Station received.	Mean No. of X's heard.
1	Miss S. A. Acland.	Oxford.	L.	13.6
2	The Observatory Staff.	Eskdalemuir, Dumfries.	L.	5.2
3	S. Morris Bower.	Huddersfield.	L.	15.2
4	C. J. P. Cave.	Petersfield.	L.	12.5
5	Joseph Clark.	Street, Somerset.	D.	10.0
6	Dr. W. W. Fyvie.	Aberdeen.	L.	58.0
7	W. L. Fox.	Falmouth.	D.	90.3
8	G. B. Hamlin.	Horeham Road, Sussex.	L.	22.3
9	Dr. E. Hall Chapman.	Matlock.	L.	10.5
10	J. Hunter.	Belper.	L.	22.8
11	Rev. H. Buckton.	Bury St. Edmunds.	L. & D.	35.9
12	D. F. Bowering.	Felixstowe.	L.	2.5
13	H. Montgomery.	Blundellsands.	L.	—
14E	J. H. Pease.	Darlington.	L.	23.3
14S	,, ,,	Pitlochry.	L. & D.	45.7
15	Col. M. St. L. Simon, C.B.E.	Holt, Norfolk.	L.	14.0
16	Mrs. A. M. Scott.	Glasgow.	L.	8.8
17	J. M. D. Simpson.	Earlston, Berwickshire.	L.	31.5
18	Major H. A. P. Littledale.	Streatley.	L.	25.6
19	—. Walker.	Crowmarsh, near Wallingford, Berks.	B. & N.	27.7
20	W. Blathwayt.	Bath, Somerset.	D.	26.6
21	J. E. Airey.	Wraysbury, near Windsor, Berks.	L.	59.9
22	Capt. R. Bureau.	Paris.	D.	29.8
24	Dr. L. Trotter.	Ledbury, Herefordshire.	D.	53.7
25	D. Trevelyan.	Kew, Surrey.	D. & L.	19.1
26	A. Wilson.	Conway.	D.	41.0
27	J. Mintern.	Cork.	D.	33.7
28	F. C. L. Richardson.	Over, Cambs.	D.	10.3
29	Rev. W. J. Young.	Milford, Tir Chonaill, I.F.S.	D.	50.6
30	G. A. L. Helder.	St. Bees, Cumberland.	D.	52.5
31	W. J. B. Rees.	Near Cardiff.	D.	7.0
32	Miss Ann Macbeth.	Penrith.	L.	10.0
33	A. Feast.	Coventry.	D.	5.3
34	T. White.	Paisley, Renfrewshire.	D.	29.0
35	M. C. Dauzère.	Hautes Pyrenees, France.	D.	53.7
36	Dr. F. Schindelhauer.	Potsdam, Germany.	D.	38.0
37	Dr. J. Bjerknes.	Bergen, Norway.	D.	58.0
38	F. C. Walker.	Funchal.	D.	41.0
39	G. L. Boag.	Murcia, Spain.	B. & D.	38.7
40	Rev. R. C. Owen.	Richmond, Yorks.	D.	1.0
42	K. Macleod.	Castlebay, Barra.	D.	6.3
43	G. W. Manson.	Lerwick, Shetland.	D.	38.8
44	A. Robinson.	Londonderry.	D.	18.0
45	Gilbert Mackereth.	Fez, Morocco.	B. & D.	19.3
46	W. J. Hale.	Newton Stewart, Wigtownshire.	D.	25.0
47	R. S. Bailey.	East Cowes.	D.	18.8
48	H. I. Jackson.	Pembroke.	D.	23.0

D=Daventry 1600 metres. L=London 365 metres. B=Bournemouth 386 metres. N=Newcastle 410 metres.

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TABLE II. a—

	37	43	6	14s	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43																								
6																								
14s																								
42																								
16																								
34																								
29																								
44																								
46																								
30																	•							
32																								
2																								
17																								
14E																								
40																	*19*			*0*		*3*		
3																	825			0		140		
13																								
26																				*2*		*1*		
9																				181		68		
10																						*2*		
15																						102		
28																								
11																								
12																								
33																								
24																								
31																								
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39																								
45																								
38																								
																	24			5		6		

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JULY 2ND. N. = 8.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
1											*0*	*4*		*1*		*2*						
264											0	44		26		97						
0											*0*	*0*		*0*		*0*						
0											0	0		0		0						
1											*0*	*2*		*1*		*1*						
286											0	24		28		53						
1											*0*	*1*		*1*		*1*						
1600											0	67		156		296						
											4	*0*		*0*		*0*						
											256	0		0		0						
												13		*3*		*3*						
												36		19		37						
														0		*1*						
														0		29						
																3						
																163						
2											4	23		4		6						

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TABLE II.

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43																								
6																								
148																								
42																								
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34																								
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44																								
46																								
30																								
32																								
2																								
17																								
14E																								
40																	*19*			*6*		*3*		
3																	825			0		140		
13																								
26																								
9																				*2*		*1*		
																				181		68		
10																						*2*		
15																						102		
28																								
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																	24			6		4		

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JULY 2ND. N. = 8.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38

TABLE II. b—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43																								
6																								
148																								
42																								
16																								
34																								
29																								
44																								
46																								
30																								
32																								
2													*3* 1108		*23* 1286		*65* 8250	*44* 3629	*59* 10765		*63* 8639			
17																								
14E															*1* 8		*24* 460	*15* 187	*20* 553		*26* 540			
40																								
3																	*6* 174	*47* 1330	*61* 3819		*58* 2727			
13																		*5* 92	*46* 1879		*52* 1592			
26																								
9																			*0* 0		*68* 4620			
10																								
15																					*2* 102			
28																								
11																								
12																								
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35																								
30																								
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38																								
													90		36		106	62	97		101			

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JULY 9TH. N. = 14.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
18		*3*		*60*	*48* *31*	*63*	*61*	*47*			
13840		577		1277	4135 4768	2021	4583	6643			
5		*1*		*22*	*15* *7*	*20*	*18*	*17*			
582		29		*71*	196 163	97	204	364			
19		*4*		*63*	*43* *25*	*63*	*57*	*45*			
5000		263		461	1272 1320	694	1470	2185			
12		*2*		*39*	*33* *20*	*50*	*45*	*38*			
2059		86		185	635 686	357	755	1201			
22		*5*		*60*	*53* *33*	*74*	*71*	*45*			
8400		475		631	2261 2508	1175	2643	3145			
21		*3*		*57*	*43* *33*	*69*	*69*	*51*			
5998		214		451	1378 1885	823	1928	2678			
0		*1*		*20*	*14* *15*	*19*	*20*	*11*			
0		400		884	2512 4800	1436	3128	3232			
		0		*6*	*3* *2*	*3*	*4*	*2*			
		0		67	134 160	50	156	147			
				22	*40* *28*	*52*	*53*	*45*			
				27	198 249	96	229	367			
					1 *24*	*47*	*49*	*33*			
					20 860	352	860	1084			
					0	*39*	*37*	*25*			
					0	521	1157	1472			
						3	*73*	*46*			
						85	475	564			
							2	*42*			
							30	1208			
								2			
								108			
27		6		120	74 51	115	101	91			

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TABLE II.—

	37 43	6 148	42 16	34 29	44 46	30 32	2 17	148 40	3 13	26 9 10 15 21
37										
43										
6										
148										
42										
16										
34										
29										
44										
46										
30										
32										
2							*4* *6* 1475 365	*10* 559	*7* 891	*1* 82	*9* *0* 1644 0	3 412
17							*7* 70	*12* 111	*7* 146	*1* 14	*5* *0* 151 0	9 294
148								*6* 51	*10* 192	*1* 13	*15* *0* 416 0	1 186
40									*12* 523	*1* 28	*9* *2* 564 58	4 188
3										*0* 0	*1* *0* 41 0	1 51
13												
26											*0* *0* 0 0	4 272
9											*3* 58	9 0
10												3 153
15												
28												
11												
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45												
38												
							20	32 42	38	2	21	5 26

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JULY 16TH. N. = 15.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 38	22 35	39 45	38
4		*2*			*6* *9*	*12*	*10*	*5*			
3072		385			515 1384	386	751	707			
4		*2*			*5* *11*	*17*	*14*	*8*			
507		63			71 279	90	174	186			
4		*4*			*11* *17*	*20*	*18*	*12*			
466		116			143 396	97	204	257			
7		*4*			*5* *8*	*20*	*15*	*9*			
1840		263			147 422	220	387	437			
1		*1*			*1* *1*	*1*	*1*	*0*			
172		43			19 34	7	17	0			
4		*3*			*8* *10*	*12*	*12*	*10*			
1524		285			341 760	190	446	699			
0		*0*			*1* *1*	*2*	*1*	*0*			
0		0			20 35	15	17	0			
2		2			*5* *5*	*12*	*13*	*5*			
571		143			160 286	143	363	263			
0		*2*			*3* *4*	*6*	*6*	*3*			
0		800			540 1280	401	938	884			
		1			*3* *4*	*4*	*4*	*3*			
		100			134 320	67	156	221			
					1 *9*	*8*	*15*	*10*			
					20 322	60	263	330			
					1	*14*	*17*	*12*			
					64	187	532	706			
						25	*34*	*17*			
						70	222	209			
							3	*20*			
							46	575			
								1			
								54			
8		9			21 27		90 51	27			

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TABLE II. d—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	1.
37																								
43																								
6																								
148																								
42																								
16																								
34																								
29																								
44																								
46																								
30																								
32																								
2																								
17														*0* 0	*0* 0		*0* 0				*0* 0	*0* 0		
14E															*5* 42		*0* 0				*1* 13	*1* 21		
40																								
3																	*5* 217				*4* 115	*0* 0		
13																								
26																								
9																								
10																					*14* 270	*0* 0		
15																						*1* 51		
28																								
11																								
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
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18																								
19																								
1																								
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35																								
39																								
45																								
38																								
														0	11		11				28	9		

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JULY 23RD. N. = 13.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38

TABLE II

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	148	40	3	13	26	9	10	15	21
37																							
43																							
6																							
148			3 15														4 57			0 0	1 10		
42																							
16																							
34																							
29																							
44																							
46																							
30																							
32																							
2																							
17																							
148																							
40																	4 174			0 0	0 0		
3																							
13																							
26																				0 0	0 0		
9																					11		
10																					212		
15																							
28																							
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5																							
48																							
27																							
7																							
47																							
8																							
4																							
25																							
21																							
18																							
19																							
1																							
36																							
22																							
35																							
39																							
45																							
38																							
				62													16			0	16		

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AUGUST 13TH. N. = 12.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
1		*2*		*1*	*8*	*45*	*50* *34*	*25*			
88		44		2	140	164	426 269	402			
1		*1*		*0*	*3*	*10*	*12* *5*	*5*			
264		66		0	158	110	310 119	243			
0		*0*		*0*	*0*	*0*	*0* *0*	*0*			
0		0		0	0	0	0 0	0			
0		*0*		*0*	*0*	*4*	*3* *1*	*1*			
0		0		0	0	29	52 16	32			
0		*0*		*0*	*2*	*2*	*4* *3*	*2*			
0		0		0	640	133	626 433	584			
		1		*0*	*0*	*4*	*3* *3*	*1*			
		100		0	0	67	117 108	73			
				0	*0*	*0*	*0* *1*	*0*			
				0	0	0	0 4	0			
					0	*8*	*9* *6*	*6*			
					0	106	282 173	354			
						23	*101* *40*	*52*			
						70	659 240	637			
							30 *40*	*50*			
							457 563	1439			
								2 *18*			
								26 477			
								7			
								379			
				1	10	145	151 54	72			

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TABLE II. (—

	37 43	6 148	42 16	34 29	44 46	30 32	2 17	14E 40	3 13	26 9	10 15 28 11
37											
43											
6											
148		*8* 38					*3* *6* 126 42		*2* 29	*0* *0* *0* 0 0 0	
42											
16											
34											
29											
44											
46											
30											
32											
2							*11* *4* 4051 243		*0* 0	*0* *1* *1* 0 84 137	
17							*16* 161		*4* 88	*0* *2* *5* 0 28 181	
14E											
40											
3									*9* 392	*0* *1* *2* 0 29 94	
13											
26											
9										*0* *0* *0* 0 0 0	
10										*3* *1* 58 31	
15										*5* 255	
28											
11											
12											
33											
24											
31											
20											
5											
48											
27											
7											
47											
8											
4											
25											
21											
18											
19											
1											
36											
22											
35											
39											
45											
38											
		22					21 40		22	0 11 20	

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SEPTEMBER 17TH N. = 12.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
		0			*0*	5	*0*	*2*			
		0			0	18	0	32			
		0			*1*	*5*	*3*	*5*			
		0			86	161	226	707			
		0			*5*	*10*	*6*	*4*			
		0			71	53	74	93			
		1			*2*	*5*	*1*	*1*			
		66			59	55	26	48			
		0			*0*	*0*	*0*	*0*			
		0			0	0	0	0			
		0			*1*	*4*	*0*	*0*			
		0			20	29	0	0			
		0			*6*	*4*	*6*	*1*			
		0			192	48	167	52			
		2			*0*	*0*	*0*	*1*			
		200			0	0	0	73			
					2	*5*	*4*	*1*			
					40	37	70	33			
						24	*11*	*5*			
						67	71	61			
							5	*5*			
							76	144			
								4			
								216			
		8			11	53	24	13			

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TABLE II. §-

	37	43	6	14s	42	16	34	29	44	46	30	32	2	17	14E,	40	3	13	26	9	10	15	28	1
37																								
43																								
6			*15* 44	*26* 98 *9*									*11* 363 *7*				*0* 0 *1*				*1* 7 *1*	*16* 197 *15*		
14s				43									296				15				10	234		
42																								
16																								
34																								
29																								
44																								
46																								
30																								
32																								
2													*5* 1847				*0* 0				*0* 0	*4* 548		
17																								
14E																								
40																								
8																	*1* 44				*0* 0	*1* 47		
13																								
26																								
9																								
10																					*0* 0	*1* 31		
15																						*11* 561		
28																								
11																								
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
10																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
			67	53									25				2				3	47		

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SEPTEMBER 24TH. N. = 10.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
		0			*8*	*45*		*27*			
		0			62	129		339			
		0			*5*	*41*		*22*			
		0			49	150		355			
		0			*2*	*13*		*7*			
		0			172	417		987			
		0			*0*	*1*		*1*			
		0			0	11		48			
		0			*1*	*2*		*1*			
		0			20	15		32			
		0			*10*	*21*		*19*			
		0			321	251		1000			
		0			*0*	*0*		*0*			
		0			0	0		0			
					3	*11*		*6*			
					60	82		198			
						32		*36*			
						89		425			
								3			
								163			
		0			23	123		44			

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TABLE II. h—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43			*2*										*16*		*17*		*2*				*4*	*9*		
6			6										530		85		23				30	*111*		
148																								
42																								
16																								
34																								
29																								
44																								
46																								
30																								
32																								
2													*1*		*11*		*1*				*5*	*4*		
17													369		614		127				422	548		
14E															*0*		*1*				*1*	*9*		
40															0		19				18	187		
3																	*1*				*1*	*3*		
13																	344				29	141		
26																								
9																								
10																					*6*	*1*		
15																					115	31		
28																						*13*		
11																						663		
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
			52										21		31		11				19	42		

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OCTOBER 8TH. N. = 13.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
11		*10*		*22*	*15*	*43*	*21*	*7*			
760		172		421	116	124	131	88			
4		*7*		*14*	*9*	*20*	*10*	*7*			
3072		135		299	775	641	693	987			
9		*10*		*19*	*12*	*29*	*14*	*10*			
1048		291		61	157	141	147	214			
2		*1*		*1*	*1*	*7*	*2*	*0*			
528		66		7	30	76	48	0			
2		*4*		*4*	*2*	*10*	*5*	*3*			
352		176		19	40	73	79	97			
5		*6*		*14*	*5*	*34*	*18*	*4*			
1428		428		111	160	406	466	210			
0		*6*		*12*	*7*	*16*	*10*	*5*			
0		2400		532	1256	1069	1440	1472			
		0		*11*	5	*16*	*7*	*4*			
		0		122	224	267	253	294			
				1	*19*	*36*	*18*	*10*			
				1	94	66	72	82			
					0	*22*	*8*	*5*			
					0	165	130	165			
						33	*44*	*20*			
						92	266	246			
							12	*10*			
							156	266			
								0			
								0			
17		17		41	25	147	65	22			

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TABLE II.

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E,	40	3	13	26	9	10	15	28	11
37																								
43																								
6																								
148																								
42																								
16																								
34																								
29																								
44																								
46																								
30																								
32																								
2																								
17																								
14E															*3*		*0*	*0*					*0*	
															25		0	0					0	
40																								
3																	*6*	*0*					*0*	
																	261	0					0	
13																		*0*					*0*	
																		0					0	
26																								
9																								
10																								
15																							102	
28																								
11																								
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
															7		5	0					5	

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OCTOBER 15TH. N. = 10.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
				0		*2*	*0* *0*	*0*	*2*		
				0		10	0 0	0	20		
				0		*0*	*0* *0*	*0*	*0*		
				0		0	0 0	0	0		
				0		*0*	*0* *0*	*0*	*0*		
				0		0	0 0	0	0		
				0		*2*	*0* *2*	*0*	*1*		
				0		24	0 52	0	24		
				0		*0*	*0* *0*	*0*	*0*		
				0		0	0 0	0	0		
						14	*0* *2*	*0*	*5*		
						30	0 12	0	28		
							0 *0*	*0*	*0*		
							0 0	0	0		
							14	*0*	*3*		
							183	0	36		
								0	*0*		
								0	0		
									28		
									316		
				0		23	0 17	0	37		

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TABLE II.—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43																								
6			*34* 101			*2* 39		*10* 34					*4* 132	*6* 33	*5* 25		*5* 57		*5* 21	*3* 49		*7* 86	*0* 0	
148																								
42																								
16						*1* 130		*3* 68					*0* 0	*3* 108	*3* 99		*1* 75		*2* 55	*2* 217		*2* 163	*1* 111	
34																								
20								*0* 0					*3* 114	*13* 82	*12* 69		*3* 39		*9* 43	*4* 75		*7* 99	*2* 38	
44																								
46																								
30																								
32																								
2													*0* 0	*3* 183	*2* 112		*0* 0		*2* 94	*0* 0		*4* 548	*0* 0	
17														*0* 0	*7* 64		*2* 42		*7* 54	*3* 91		*7* 159	*2* 61	
14E															*2* 17		*2* 38		*4* 28	*3* 83		*6* 124	*2* 56	
40																								
3																	*4* 174		*2* 32	*1* 63		*1* 47	*0* 0	
13																								
26																			*0* 0	*2* 46		*5* 87	*1* 23	
9																				*0* 0		*3* 204	*2* 184	
10																								
15																								
28																						*0* 0	*2* 133	
11																								
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
	63		4		33					6	16	33			15		11	5		15		2		

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OCTOBER 27TH. N. = 25.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45 38
0	*1*	*12* *1*	*6*		*4*	*7* *11*	*9* *12*	*11*	*7*	*8*
0	24	78 17	31		31	63 32	61 75	139	41	36
0	*0*	*3* *1*	*3*		*2*	*3* *3*	*3* *3*	*2*	*2*	*3*
0	0	128 114	101		103	178 57	133 123	168	76	88
0	*1*	*12* *2*	*15*		*3*	*11* *14*	*10* *17*	*10*	*12*	*16*
0	29	89 40	88		27	114 46	77 121	146	80	82
0	*1*	*3* *0*	*2*		*2*	*3* *5*	*3* *3*	*3*	*1*	*3*
0	275	217 0	114		172	302 161	226 208	424	65	149
0	*1*	*10* *2*	*9*		*4*	*9* *9*	*9* *13*	*8*	*7*	*10*
0	46	120 63	85		57	150 48	112 149	186	75	82
0	*0*	*8* *1*	*12*		*3*	*9* *14*	*8* *19*	*6*	*15*	*17*
0	0	88 29	104		39	137 68	91 199	128	146	127
0	*0*	*3* *0*	*2*		*1*	*2* *5*	*2* *3*	*4*	*2*	*2*
0	0	74 0	39		30	69 55	52 71	194	44	34
0	*1*	*8* *1*	*6*		*3*	*6* *6*	*7* *7*	*9*	*5*	*5*
0	34	73 24	43		33	77 25	67 62	162	41	31
0	*0*	*3* *1*	*3*		*1*	*3* *3*	*2* *3*	*2*	*3*	*3*
0	0	108 95	115		43	150 48	74 103	140	96	74
0	*1*	*10* *1*	*8*		*3*	*8* *8*	*8* *11*	*7*	*5*	*5*
0	102	268 71	170		96	299 95	223 283	368	120	129
0	*0*	*2* *0*	*2*		*0*	*2* *1*	*1* *2*	*1*	*2*	*2*
0	0	73 0	57		0	102 17	38 70	72	65	50
0	*1*	*12* *2*	*13*		*4*	*12* *14*	*14* *20*	*11*	*8*	*14*
0	40	126 56	108		50	175 65	152 201	225	75	101
0	*0*	*0* *0*	*0*		*0*	*0* *0*	*0* *0*	*0*	*0*	*0*
0	0	0 0	0		0	0 0	0 0	0	0	0
	0	*1* *0*	*0*		*0*	*1* *1*	*1* *1*	*1*	*0*	*1*
	0	54 0	0		0	74 24	56 51	106	0	52
		16 *4*	*11*		*4*	*12* *14*	*12* *14*	*12*	*7*	*10*
		226 150	123		68	236 88	176 190	332	88	97
		3	*1*		*1*	*1* *2*	*1* *2*	*1*	*1*	*2*
		300	30		45	52 33	39 72	74	34	52
			1		*4*	*13* *11*	*9* *13*	*7*	*10*	*12*
			9		53	202 55	104 139	153	100	92
					0	*4* *4*	*4* *4*	*7*	*2*	*2*
					0	94 30	70 65	231	30	23
						1 *11*	*10* *12*	*9*	*8*	*11*
						27 96	204 226	346	140	149
						6 *12*	*12* *10*		*10*	*13*
						17 78	72 123		56	56
						0 *14*	*11*		*8*	*10*
						0 234	316		105	101
						6	*12*		*12*	*19*
						78	319		145	177
							0		*9*	*7*
							0		222	133
									11	*13*
									124	112
										3
										20
	1	46 7	24		7	17 36	18 40	16	37	32

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TABLE II. *k*—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
	17	*19*			*7*			*28*	*13*				*8*	*18*	*25*	*0*	*7*		*5*	*5*		*3*	*7*	*14*
37	50	85			192			95	125				265	98	125	0	79		21	82		37	117	67
		6			*1*			*22*	*14*				*7*	*14*	*15*	*0*	*4*		*6*	*3*		*2*	*7*	*4*
43		40			41			112	201				348	115	112	0	68		38	74		37	175	57
6																								
148																								
					1			*5*	*6*				*3*	*8*	*6*	*0*	*3*		*2*	*5*		*3*	*2*	*4*
42					251			157	527				917	404	277	0	313		78	757		340	308	171
16																								
34																								
								6	*12*				*10*	*26*	*29*	*0*	*2*		*9*	*7*		*2*	*13*	*3*
29								24	132				380	163	167	0	26		44	132		28	249	11
									3				*8*	*19*	*17*	*0*	*2*		*8*	*5*		*5*	*4*	
44									93				856	335	275	0	73		108	265		198	216	106
46																								
30																								
32																								
													1	*10*	*8*	*0*	*1*		*3*	*4*		*3*	*4*	*6*
2													869	609	448	0	127		141	730		412	746	321
														0	*29*	*0*	*4*		*10*	*9*		*5*	*8*	*12*
17														0	267	0	83		78	271		113	247	146
															1	*0*	*4*		*9*	*8*		*4*	*10*	*14*
14E															8	0	77		64	222		83	283	115
																0	*0*		*0*	*0*		*0*	*0*	*0*
40																0	0		0	0		0	0	0
																	5		*1*	*2*		*1*	*1*	*2*
3																	217		16	125		47	64	19
13																								
																			1	*6*		3	6	1
26																			6	139		52	142	21
																				0		5	4	3
9																				0		340	370	122
10																								
																						1	*2*	1
15																						51	139	6
																							0	3
28																							0	18
																								1
11																								21
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
	81	49			9			56	28				16	48	42	0	12		17	16		10	15	38

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NOVEMBER 3RD. N. = 32.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
3		*6*	*4*	*16*	*7*		*27*			*2*	*4*	*6*	*35*	*16*	*19*	*8*	*15*		*26*	*17*		*4*
206		19	98	104	120		138			15	55	54	100	108	118	101	68		83	76		17
2		*4*	*4*	*10*	*3*		*22*			*1*	*8*	*6*	*32*	*17*	*10*	*4*	*13*		*16*	*11*		*2*
206		19	148	97	77		168			12	165	81	138	171	93	76	88		77	73		13
2		*4*	*2*	*4*	*3*		*6*			*1*	*2*	*4*	*7*	*5*	*4*	*1*	*4*		*6*	*3*		*0*
1272		118	455	238	477		283			716	254	333	186	310	229	118	146		178	124		0
1		*11*	*5*	*16*	*2*		*30*			*5*	*8*	*13*	*35*	*23*	*22*	*5*	*21*		*32*	*20*		*2*
79		403	142	119	40		176			44	127	135	116	178	157	73	109		118	102		10
3		*5*	*4*	*11*	*4*		*20*			*3*	*4*	*6*	*18*	*12*	*8*	*7*	*9*		*11*	*9*		*0*
667		52	318	230	222		330			75	178	175	167	261	161	286	132		114	129		0
3		*4*	*5*	*7*	*2*		*10*			*2*	*4*	*2*	*9*	*9*	*5*	*5*	*5*		*4*	*3*		*0*
2308		143	1376	508	385		57			172	614	201	288	676	347	707	254		143	149		0
4		*11*	*8*	*17*	*4*		*28*			*5*	*9*	*14*	*35*	*28*	*19*	*9*	*13*		*26*	*15*		*0*
507		65	363	203	127		264			71	228	232	185	347	218	210	109		153	123		0
2		*9*	*7*	*18*	*2*		*29*			*3*	*6*	*13*	*37*	*21*	*23*	*9*	*17*		*29*	*22*		*0*
233		49	290	197	58		250			39	140	198	180	235	241	193	130		157	165		0
0		*0*	*0*	*0*	*0*		*0*			*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*		*0*
0		0	0	0	0		0			0	0	0	0	0	0	0	0		0	0		0
2		*0*	*0*	*3*	*2*		*4*			*1*	*1*	*0*	*5*	*5*	*3*	*1*	*2*		*6*	*2*		*0*
528		0	0	74	132		78			30	53	0	55	129	71	49	35		74	34		0
2		*4*	*4*	*6*	*2*		*7*			*2*	*4*	*7*	*16*	*9*	*3*	*3*	*2*		*9*	*8*		*0*
195		18	140	55	49		51			22	78	90	65	86	26	54	13		41	50		0
2		*5*	*2*	*10*	*3*		*6*			*3*	*5*	*9*	*11*	*9*	*3*	*5*	*3*		*6*	*6*		*0*
760		89	272	358	285		170			128	380	448	175	335	103	350	75		106	147		0
2		*0*	*2*	*4*	*2*		*3*			*2*	*2*	*4*	*6*	*6*	*0*	*3*	*3*		*3*	*4*		*0*
57		0	204	108	143		64			64	114	150	71	167	0	158	56		40	74		0
2		*6*	*4*	*10*	*3*		*13*			*2*	*5*	*8*	*13*	*6*	*4*	*3*	*9*		*8*	*7*		*0*
777		109	556	365	291		375			87	388	407	211	227	140	215	230		144	175		0
3		*6*	*5*	*7*	*1*		*15*			*5*	*5*	*7*	*19*	*13*	*17*	*5*	*13*		*16*	*13*		*2*
336		31	199	73	28		124			62	111	102	88	142	171	102	95		83	93		14
0		*1*	*2*	*3*	*3*		*2*			*2*	*2*	*1*	*3*	*4*	*1*	*3*	*1*		*1*	*1*		*0*
0		74	1140	451	1200		238			360	640	209	200	626	144	884	105		74	103		0
		3	*5*	*5*	*1*		*9*			*3*	*2*	*9*	*13*	*7*	*7*	*3*	*7*		*9*	*6*		*0*
		10	133	35	19		50			25	30	88	40	47	47	41	34		31	29		0
			0	*6*	*1*		*6*			*3*	*4*	*5*	*6*	*8*	*5*	*4*	*4*		*5*	*2*		*0*
			0	323	143		255			193	458	375	144	446	257	420	150		133	74		0
				1	*5*		*17*			*3*	*5*	*10*	*21*	*13*	*10*	*9*	*7*		*11*	*7*		*1*
				14	188		190			51	150	197	132	191	136	249	69		77	68		9
					1		*3*			*1*	*1*	*1*	*4*	*3*	*1*	*2*	*3*		*1*	*2*		*0*
					100		89			45	80	52	67	117	36	146	79		19	52		0
							8			*5*	*10*	*9*	*37*	*21*	*24*	*6*	*18*		*31*	*19*		*3*
							70			67	238	140	183	244	257	131	140		171	146		22
										0	*3*	*4*	*5*	*4*	*3*	*2*	*4*		*3*	*4*		*0*
										0	108	94	37	70	49	65	47		25	46		0
											4	*5*	*12*	*7*	*5*	*3*	*4*		*6*	*4*		*0*
											256	209	160	219	144	177	84		89	83		0
												1	*15*	*12*	*7*	*4*	*7*		*11*	*9*		*0*
												27	131	245	132	154	97		107	122		0
													4	*28*	*29*	*8*	*23*		*42*	*30*		*3*
													11	182	175	98	101		130	129		12
														1	*18*	*9*	*12*		*24*	*15*		*1*
														15	254	259	123		174	151		10
															1	*5*	*11*		*21*	*14*		*1*
															13	133	104		141	131		9
																1	*2*		*5*	*1*		*0*
																54	38		68	19		0
																	1		*20*	*14*		*1*
																	7		98	95		6
																			5	*24*		*2*
																			17	115		9
																				0		*2*
																				0		13
																						2
																						12
4		25	12	31	8		57			8	22	18	78	31	37	12	34		47	33		5

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TABLE II.—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28
	4	*8*			*1*	*5*	*7*		*5*	*9*	*5*	*2*	*7*	*9*	*1*	*1*		*7*		*0*	*1*	*1*	
37	12	36			27	98	24		34	29	86	66	38	45	170	11		29		0	12	65	
		8			*5*	*6*	*11*		*11*	*13*	*10*	*1*	*11*	*13*	*3*	*2*		*17*		*1*	*4*	*11*	
43		53			122	176	56		114	64	258	50	90	98	776	34		107		11	74	25	
6																							
148																							
					0	*3*	*7*		*6*	*5*	*2*	*1*	*5*	*5*	*2*	*2*		*5*		*1*	*6*	*5*	
42					0	542	219		379	151	318	305	253	231	318	210		194		70	681	771	
						1	*9*		*6*	*9*	*6*	*2*	*11*	*10*	*1*	*2*		*11*		*0*	*3*	*1*	
16						130	202		272	195	681	439	396	3321	140	150		305		0	244	982	
34																							
							0		*12*	*18*	*7*	*2*	*17*	*15*	*1*	*6*		*20*		*3*	*6*	*16*	
29							0		95	68	138	76	107	86	200	78		97		26	85	307	
44																							
									2	*17*	*9*	*2*	*14*	*5*	*2*	*9*		*19*		*3*	*4*	*12*	
46									32	130	360	154	178	174	800	238		185		53	114	464	
										0	*7*	*4*	*25*	*19*	*2*	*11*		*29*		*3*	*5*	*15*	
30										0	133	147	152	105	380	139		135		25	68	221	
											1	*2*	*9*	*11*	1	*2*		*12*		*1*	*1*	*3*	
32											100	385	286	3201	000	132		292		44	71	571	
												0	*3*	*2*	*0*	*1*		*3*		*0*	*1*	*3*	
2												0	183	112	0	127		141		0	137	56	
													0	*21*	*1*	*7*		*24*		*1*	*6*	*13*	
17													0	194	320	146		217		14	134	442	
														1	*3*	*4*		*24*		*4*	*4*	*11*	
14E														8	870	77		170		51	83	258	
															1	*0*		*1*		*0*	*2*	*7*	
40														10000		0		240		0	143	97	
																0		*11*		*2*	*2*	*7*	
3																0		177		58	94	64	
13																							
																			1		*3*	*4*	*20*
26																			6		32	70	462
9																							
																					0	*0*	*2*
10																					0	0	4
																						0	*1*
15																						0	34
																							2
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38																							
	19	29			11	14	24		25	39	17	4	31	27	4	15		41		6	14	28	

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NOVEMBER 10TH. N. = 32.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
	4 *1*	*2* *1*	*3* *4*		*1*	*3* *8*	*3* *3*	*5*		*2* *3*	
	13 25	13 17	23 20		8	27 23	20 19	63		9 27	
	8 *2*	*3* *1*	*1* *5*		*1*	*4* *15*	*5* *5*	*6*		*2* *5*	
	38 74	29 26	11 38		12	54 65	50 46	114		13 66	
	4 *0*	*1* *2*	*3* *2*		*1*	*4* *5*	*6* *2*	*4*		*2* *2*	
	118 0	60 318	206 94		78	334 132	372 114	467		83 164	
	5 *1*	*1* *1*	*0* *8*		*1*	*7* *9*	*7* *4*	*5*		*3* *3*	
	106 163	43 114	0 270		51	416 170	311 164	420		88 177	
	11 *2*	*6* *2*	*3* *7*		*2*	*12* *12*	*10* *7*	*13*		*5* *5*	
	40 57	45 40	26 41		18	125 40	77 50	189		26 51	
	13 *2*	*5* *2*	*6* *8*		*3*	*10* *17*	*9* *6*	*10*		*4* *5*	
	97 114	75 80	104 95		54	209 114	141 186	294		41 104	
	16 *2*	*9* *2*	*9* *9*		*3*	*15* *19*	*12* *7*	*16*		*5* *5*	
	57 54	65 38	74 51		26	150 61	90 48	225		25 49	
	5 *2*	*4* *2*	*2* *7*		*1*	*4* *8*	*5* *6*	*5*		*3* *2*	
	93 286	150 200	87 208		45	210 133	195 216	368		77 104	
	1 *0*	*2* *1*	*0* *2*		*1*	*2* *3*	*2* *2*	*2*		*1* *0*	
	36 0	145 192	0 114		86	201 96	151 139	280		50 0	
	12 *1*	*11* *3*	*6* *10*		*3*	*14* *17*	*13* *6*	*14*		*5* *5*	
	71 46	131 95	83 94		43	232 90	161 69	327		41 82	
	9 *2*	*9* *3*	*5* *10*		*1*	*11* *17*	*10* *7*	*15*		*2* *4*	
	49 83	99 87	63 86		13	167 82	114 73	320		15 60	
	2 *0*	*0* *0*	*1* *1*		*0*	*1* *1*	*1* *1*	*1*		*0* *0*	
	370 0	0 0	435 300		0	520 170	390 360	740		0 0	
	8 *1*	*3* *1*	*4* *3*		*2*	*8* *9*	*4* *2*	*6*		*5* *2*	
	98 94	740 66	114 59		59	276 99	103 48	294		85 68	
	19 *4*	*16* *4*	*8* *12*		*3*	*17* *28*	*16* *8*	*14*		*6* 5	
	86 140	147 98	85 87		33	217 114	153 70	251		38 63	
	3 *3*	*1* *0*	*1* *0*		*0*	*1* *3*	*1* *0*	*2*		*1* *1*	
	25 189	17 0	19 0		0	23 22	17 0	64		11 23	
	4 *0*	*3* *3*	*1* *3*		*0*	*4* *2*	*3* *3*	*4*		*3* *4*	
	53 0	80 214	31 64		0	150 24	84 77	210		55 148	
	17 *3*	*9* *3*	*6* *1*		*3*	*15* *21*	*9* *6*	*12*		*5* *6*	
	307 416	328 291	253 231		131	763 341	342 210	857		125 252	
	8 *1*	*7* *3*	*4* *6*		*2*	*10* *11*	*11* *6*	*11*		*4* *3*	
	41 40	73 83	48 50		25	145 51	120 60	225		29 44	
	2 *3*	*9* *3*	*6* *6*		*2*	*11* *17*	*8* *5*	*8*		*3* *2*	
	7 80	63 56	49 33		17	107 53	58 33	109		14 19	
	0	*2* *0*	*0* *1*		*1*	*1* *3*	*1* *1*	*1*		*1* *1*	
	0	107 0	0 43		64	74 71	56 52	106		37 74	
		1 *3*	*4* *3*		*1*	*5* *10*	*7* *4*	*6*		*2* *0*	
		14 113	65 34		17	98 63	103 54	166		19 0	
		0	*1* *1*		*0*	*3* *4*	*3* *2*	*2*		*1* *0*	
		0	44 30		0	157 67	117 72	146		26 0	
			6 *2*		*2*	*3* *6*	*6* *0*	*4*		*0* *3*	
			114 26		39	68 44	102 0	128		0 67	
			1		*1*	*7* *6*	*6* *4*	*5*		*3* *1*	
			9		13	109 30	69 43	80		23 16	
					0	*3* *3*	*3* *1*	*3*		*0* *0*	
					0	71 23	53 16	65		0 0	
						0 *15*	*10* *5*	*10*		*4* *1*	
						0 131	204 94	385		54 27	
						3	*14* *4*	*10*		*3* *4*	
						8	91 24	123		13 35	
							2 *4*	*6*		*3* *2*	
							30 56	172		30 40	
							3	*7*		*1* *0*	
							39	186		9 0	
								0		*1* *2*	
								0		19 76	
										0 *3*	
										0 40	
										0	
										0	
	29 7	18 5	24 13		3	18 42	20 12	16		7 8	

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TABLE II.

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
	8				*13*	*16*	*54*								*50*	*2*	*14*		*78*		*23*		*9*	
37	24				254	95	184								249	340	159		327		173		150	
43																								
6																								
148																								
42																								
						0	*10*	*15*							*18*	*1*	*5*		*17*		*10*		*5*	
16						0	393	339							596	1140	375		471		500		552	
							1	*17*							*18*	*1*	*4*		*23*		*15*		*5*	
34							12	116							180	340	91		194		227		166	
								4							*50*	*1*	*14*		*69*		*18*		*9*	
29								16							287	200	183		333		156		173	
44																								
46																								
30																								
32																								
2																								
17																								
															1	*1*	*12*		*62*		*27*		*15*	
14E															8	290	229		439		343		283	
																0	*1*		*2*		*1*		*6*	
40																0	660		490		440		0	
																	1		*15*		*6*		*3*	
3																	44		242		173		191	
13																								
																			0		*31*		*15*	
26																			0		332		284	
9																								
																					0		*9*	
10																					0		384	
15																								
																							1	
28																							94	
11																								
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38																								
	114				18	29	100								90	3	28		119		36		14	

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NOVEMBER 18TH. N.=29.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
1	*8*	*37*	*7*	*22*	*6*		*48*	*79*		*40*		*45*	*77*	*49*	*28*	*15*		*31*	*75*	*104*		*36*
69	260	118	172	142	103		244	150		307		406	220	329	174	189		179	241	462		152
1	*5*	*15*	*4*	*8*	*3*		*16*	*17*		*13*		*14*	*18*	*14*	*15*	*7*		*6*	*12*	*14*		*8*
456	1074	318	651	342	342		541	214		665		832	340	622	617	587		229	253	410		222
1	*6*	*15*	*3*	*10*	*2*		*20*	*22*		*12*		*16*	*24*	*17*	*15*	*8*		*6*	*18*	*18*		*11*
138	390	96	148	130	69		205	84		186		289	138	229	187	203		69	116	160		92
1	*6*	*36*	*6*	*24*	*4*		*48*	*76*		*33*		*45*	*65*	*48*	*34*	*19*		*29*	*59*	*48*		*32*
79	223	133	169	179	79		281	167		293		467	214	372	244	277		193	216	245		154
2	*7*	*36*	*8*	*25*	*4*		*49*	*71*		*39*		*48*	*62*	*50*	*39*	*21*		*30*	*63*	*55*		*34*
233	384	195	332	273	116		422	228		509		732	301	567	408	448		293	340	413		241
0	*0*	*1*	*0*	*0*	*1*		*2*	*1*		*1*		*1*	*1*	*1*	*1*	*0*		*1*	*1*	*1*		*0*
0	0	190	0	0	1000		590	110		450		520	170	390	360	0		340	190	260		0
1	*1*	*13*	*3*	*4*	*2*		*13*	*17*		*9*		*12*	*16*	*13*	*8*	*6*		*6*	*16*	*9*		*9*
264	125	160	282	99	132		255	124		266		414	177	335	190	291		133	197	153		145
2	*9*	*45*	*8*	*34*	*5*		*59*	*103*		*52*		*61*	*93*	*59*	*40*	*19*		*36*	*82*	*72*		*43*
195	416	204	279	312	122		428	278		569		781	378	561	351	342		295	372	454		256
1	*7*	*22*	*5*	*13*	*6*		*20*	*34*		*16*		*26*	*34*	*17*	*17*	*9*		*12*	*24*	*25*		*16*
176	580	179	313	214	263		260	165		315		596	249	292	269	291		177	195	284		171
1	*7*	*11*	*4*	*9*	*5*		*10*	*13*		*7*		*9*	*10*	*9*	*4*	*7*		*4*	*10*	*9*		*10*
388	1285	198	556	328	486		287	140		305		457	162	342	140	500		130	181	225		237
0	*7*	*37*	*8*	*21*	*3*		*57*	*83*		*44*		*52*	*77*	*47*	*38*	*18*		*29*	*64*	*59*		*34*
0	369	192	317	220	83		472	255		548		758	357	512	383	367		271	331	423		231
0	*1*	*0*	*1*	*1*	*0*		*2*	*2*		*1*		*2*	*2*	*2*	*1*	*1*		*1*	*1*	*1*		*0*
0	756	0	572	150	0		238	88		180		418	134	313	144	296		134	74	103		0
	0	*8*	*2*	*8*	*3*		*7*	*9*		*6*		*8*	*10*	*8*	*4*	*3*		*4*	*5*	*7*		*5*
	0	282	541	569	567		393	180		508		792	316	590	272	418		253	175	341		230
		3	*5*	*21*	*6*		*37*	*59*		*26*		*32*	*49*	*30*	*23*	*13*		*20*	*45*	*31*		*24*
		10	133	147	112		205	121		218		312	152	218	155	178		125	156	149		109
			0	*6*	*1*		*5*	*10*		*6*		*5*	*9*	*7*	*4*	*4*		*6*	*8*	*6*		*3*
			0	323	143		212	159		385		375	215	390	206	420		287	212	221		105
				2	*3*		*23*	*39*		*19*		*22*	*36*	*23*	*18*	*10*		*12*	*29*	*30*		*22*
				29	113		257	162		321		433	225	338	244	277		152	203	292		202
					0		*5*	*9*		*2*		*4*	*6*	*3*	*2*	*3*		*0*	*3*	*5*		*3*
					0		149	100		90		209	100	117	72	221		0	58	129		73
							2	*63*		*40*		*44*	*61*	*46*	*32*	*18*		*22*	*58*	*46*		*28*
							18	207		532		683	303	534	345	392		219	320	353		203
								6		*55*		*62*	*104*	*68*	*45*	*21*		*50*	*105*	*83*		*53*
								7		272		359	192	294	180	171		186	216	237		143
										0		*36*	*50*	*32*	*27*	*11*		*25*	*49*	*38*		*36*
										0		852	374	559	437	362		376	409	438		397
												0	*57*	*35*	*24*	*11*		*24*	*47*	*46*		*31*
												0	497	717	453	423		421	458	622		395
													4	*62*	*46*	*23*		*36*	*87*	*71*		*45*
													11	404	277	282		202	270	307		183
														2	*34*	*18*		*25*	*58*	*43*		*34*
														30	480	516		328	420	433		324
															0	*18*		*14*	*37*	*33*		*20*
															0	477		170	249	307		176
																0		*6*	*18*	*17*		*11*
																0		148	245	322		197
																		0	*43*	*30*		*22*
																		0	268	260		180
																			5	*74*		*42*
																			17	356		191
																				3		*43*
																				20		270
																						1
																						6
2	11	84	13	45	9		70	170		68		67	145	83	49	24		61	130	108		55

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TABLE II. *n*—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
	8	*0*	*23*		*0*			*15*	*5*		*20*	*2*	*2*		*19*	*0*			*22*		*10*	*19*	*3*	*12*
37	24	0	68		0			51	48		66	34	66		95	0			92		75	233	50	57
		4	*3*		*0*			*3*	*0*		*2*	*0*	*0*		*2*	*0*			*1*		*0*	*1*	*0*	*0*
43		27	13		0			15	0		10	0	0		15	0			6		0	18	0	0
			9		*0*			*20*	*5*		*25*	*2*	*3*		*22*	*0*			*24*		*14*	*19*	*2*	*12*
6			27		0			68	29		82	34	99		111	0			101		106	234	33	58
148																								
					0			*0*	*0*		*0*	*0*	*0*		*0*	*0*			*0*		*0*	*0*	*0*	*0*
42					0			0	0		0	0	0		0	0			0		0	0	0	0
16																								
34																								
								4	*6*		*18*	*1*	*2*		*18*	*0*			*22*		*11*	*22*	*3*	*11*
29								16	66		68	20	76		104	0			106		96	311	58	61
									0		*6*	*0*	*2*		*6*	*0*			*3*		*3*	*6*	*1*	5
44									0		63	0	214		97	0			108		73	238	54	77
46																								
											8	*4*	*2*		*16*	*0*			*25*		*15*	*19*	*1*	*11*
30											29	76	74		89	0			117		126	260	18	56
												3	*0*		*1*	*0*			*1*		*0*	*1*	*0*	*2*
32												300	0		29	0			24		0	71	0	56
													1		*2*	*0*			*2*		*2*	*2*	*1*	*2*
2													369		112	0			94		169	275	186	107
17																								
															1	*0*			*22*		*9*	*20*	*2*	*12*
14E															8	0			156		115	416	56	97
40																*0*			*0*		*0*	*0*	*0*	*0*
																0			0		0	0	0	0
3																								
13																								
																			0		*12*	*23*	*2*	*14*
26																			0		128	400	48	95
9																								
																					2	*9*	*3*	*8*
10																					39	282	127	96
																						1	*3*	*12*
15																						51	208	23
																							0	*1*
28																							0	27
																								0
11																								0
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
	57	12	58		0			48	8		66	13	6		35	0			40		25	32	4	17

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NOVEMBER 25TH. N. = 37.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
0	*1*	*18*	*1*	*6*	*7*	*21*	*18*	*26*	*15*	*3*		*6*	*12*	*12*	*21*	*10*	*23*	*13*		*16*	*12*	*15*
0	33	58	25	39	120	157	92	50	137	23		54	34	81	130	127	104	75		71	107	63
0	*0*	*2*	*0*	*0*	*0*	*1*	*0*	*5*	*1*	*0*		*1*	*1*	*0*	*2*	*0*	*1*	*1*		*0*	*1*	*3*
0	0	10	0	0	0	11	0	14	14	0		13	4	0	19	0	7	9		0	13	19
0	*4*	*22*	*1*	*8*	*3*	*29*	*17*	*34*	*14*	*0*		*5*	*15*	*9*	*24*	*11*	*27*	*13*		*14*	*10*	*15*
0	130	70	24	52	52	218	87	65	128	0		45	43	61	149	139	122	75		62	89	63
0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0		0	0	0
0	*3*	*24*	*1*	*5*	*5*	*21*	*17*	*13*	*16*	*3*		*8*	*14*	*13*	*24*	*13*	*21*	*13*		*16*	*15*	*12*
0	112	88	29	37	99	181	100	29	168	27		83	46	101	171	189	109	86		81	153	58
0	*1*	*6*	*0*	*1*	*3*	*7*	*7*	*6*	*4*	*2*		*3*	*5*	*4*	*7*	*5*	*7*	*5*		*4*	*4*	*4*
0	105	62	0	21	167	169	116	37	118	50		58	46	87	140	205	102	93		57	115	54
0	*3*	*22*	*0*	*11*	*3*	*26*	*17*	*26*	*14*	*7*		*4*	*19*	*11*	*25*	*12*	*24*	*10*		*16*	*75*	*12*
0	108	78	0	79	57	215	96	55	142	60		40	61	82	172	169	120	64		78	200	56
0	*0*	*1*	*0*	*2*	*1*	*2*	*1*	*3*	*1*	*0*		*0*	*2*	*0*	*1*	*0*	*0*	*1*		*1*	*1*	*1*
0	0	19	0	75	100	87	30	55	53	0		0	33	0	36	0	0	34		26	52	98
0	*1*	*2*	*1*	*1*	*2*	*2*	*2*	*3*	*2*	*0*		*2*	*0*	*2*	*2*	*2*	*3*	*2*		*1*	*0*	*2*
0	363	72	275	72	385	167	114	64	205	0		201	0	151	139	280	152	129		49	0	94
0	*1*	*16*	*1*	*6*	*7*	*26*	*19*	*26*	*16*	*4*		*5*	*13*	*10*	*26*	*13*	*25*	*12*		*12*	*9*	*12*
0	55	86	41	65	204	329	164	84	248	52		76	63	114	273	278	191	117		90	136	85
0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0		0	0	0
0	*4*	*25*	*2*	*9*	*5*	*32*	*20*	*24*	*20*	*7*			*21*	*15*	*28*	*13*	*31*	*12*		*19*	*15*	*9*
0	185	113	70	82	122	233	145	65	260	77		115	86	143	246	233	199	98		119	190	54
0	*2*	*16*	*1*	*5*	*5*	*11*	*7*	*15*	*8*	*4*		*6*	*7*	*10*	*13*	*7*	*12*	*6*		*8*	*5*	*7*
0	166	131	63	82	220	210	93	73	187	79		141	51	171	206	226	138	90		90	113	77
0	*2*	*17*	*2*	*6*	*4*	*24*	*19*	*19*	*19*	*5*		*8*	*12*	*13*	*26*	*13*	*25*	*10*		*19*	*12*	*9*
0	270	225	204	161	286	743	404	150	723	160		299	143	363	671	683	471	240		350	444	157
0	*0*	*2*	*1*	*2*	*2*	*1*	*2*	*3*	*3*	*0*		*2*	*1*	*3*	*2*	*2*	*2*	*0*		*2*	*1*	*2*
0	0	36	139	73	194	42	57	32	155	0		102	17	114	70	142	51	0		50	50	47
0	*1*	*8*	*0*	*5*	*4*	*15*	*13*	*13*	*11*	*7*		*6*	*11*	*10*	*16*	*7*	*14*	*10*		*9*	*7*	*5*
0	53	41	0	52	111	182	108	40	163	87		87	51	109	161	143	103	93		64	101	34
0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0		0	0	0
	0	*4*	*0*	*1*	*0*	*2*	*1*	*2*	*2*	*0*		*1*	*4*	*1*	*2*	*1*	*1*	*1*		*2*	*1*	*0*
	0	140	0	72	0	164	57	416	201	0		98	127	74	136	140	50	64		98	98	0
		13	*2*	*7*	*5*	*27*	*15*	*25*	*15*	*6*		*7*	*18*	*13*	*22*	*13*	*24*	*13*		*16*	*16*	*14*
		45	53	49	93	218	83	51	148	50		68	56	94	148	178	117	81		77	154	63
			1	*1*	*1*	*2*	*1*	*1*	*2*	*1*		*2*	*1*	*2*	*2*	*1*	*2*	*0*		*0*	*1*	*0*
			204	54	143	124	43	16	152	64		150	24	112	103	106	75	0		0	74	0
				3	*3*	*9*	*5*	*11*	*6*	*3*		*2*	*5*	*6*	*10*	*5*	*9*	*5*		*6*	*6*	*6*
				42	113	147	56	46	120	51		39	31	88	136	138	89	63		58	117	55
					1	*4*	*4*	*7*	*4*	*0*		*3*	*4*	*2*	*5*	*3*	*3*	*3*		*3*	*4*	*5*
					100	174	119	78	213	0		157	67	78	180	221	79	101		77	207	122
						2	*22*	*31*	*17*	*7*		*7*	*19*	*15*	*35*	*17*	*37*	*16*		*17*	*15*	*13*
						38	284	149	303	137		160	138	255	548	544	424	234		191	338	138
							0	*21*	*14*	*6*		*7*	*13*	*12*	*22*	*13*	*20*	*9*		*16*	*14*	*9*
							0	69	221	80		109	64	139	236	284	156	90		122	215	65
								15	*17*	*7*		*8*	*20*	*15*	*28*	*15*	*27*	*19*		*16*	*16*	*27*
								18	100	34		46	37	65	112	122	70	71		45	92	73
									1	*4*		*7*	*14*	*12*	*18*	*11*	*17*	*6*		*11*	*8*	*8*
									28	96		195	124	250	346	430	238	107		151	220	104
										2		*3*	*3*	*6*	*7*	*3*	*7*	*3*		*5*	*2*	*2*
										40		71	23	105	113	99	83	45		58	46	22
												0	*4*	*8*	*9*	*8*	*9*	*3*		*7*	*4*	*3*
												0	35	163	170	308	124	53		94	109	38
													5	*9*	*19*	*8*	*18*	*8*		*11*	*10*	*11*
													14	59	115	98	79	45		47	87	45
														1	*17*	*12*	*15*	*8*		*12*	*7*	*6*
														15	240	345	154	105		121	142	57
															1	*14*	*36*	*5*		*20*	*14*	*10*
															13	372	342	61		186	262	88
																0	*17*	*8*		*11*	*9*	*5*
																0	329	198		208	343	90
																	1	*17*		*17*	*15*	*10*
																	7	150		115	205	64
																		3		*6*	*4*	*7*
																		34		52	69	57
																				0	*13*	*8*
																				0	174	50
																					4	*10*
																					107	126
																						14
																						83
0	5	78	4	28	14	43	29	87	25	12		10	49	19	50	20	48	29		29	36	65

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TABLE II. o—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
37																								
43		*15* 100			*3* 122			*30* 153					*1* 50	*25* 205	*10* 75	*0* 0	*6* 102						*3* 75	21 151
6																								
148																								
42					*0* 0			*4* 126					*0* 0	*2* 102	*0* 0	*0* 0	*1* 105						*0* 0	154
16																								
34																								
29								*4* 16					*1* 38	*23* 145	*5* 29	*0* 0	*6* 78						*2* 38	
44																								
46																								
30																								
32																								
2													*0* 0	*1* 61	*0* 0	*0* 0	*0* 0						*0* 0	1
17														*1* 10	*4* 37	*0* 0	*1* 21						0 62	133
14E															*1* 8	*0* 0	*3* 57						*2* 56	57
40																*0* 0	*0* 0						0	0
3																	*3* 130						*1* 64	5 91
13																								
26																								
9																								
10																								
15																								
28																							*0* 0	3 82
11																								14 106
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
	104				5		58						1	37	13	0	13						3	61

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DECEMBER 9TH. N. = 28.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
	2	28	3	16	6	11	24		21	18		12	10	6	4	7	50	18	9	38		
	98	134	111	155	155	124	184		288	208		162	43	60	37	133	340	156	43	253		
	0	1	0	1	2	1	4		1	1		1	0	2	1	3	1	1	2	2		
	0	30	0	60	318	69	189		84	72		83	0	124	57	351	41	54	59	83		
	1	22	2	16	4	11	25		16	7		11	10	6	6	6	27	13	7	26		
	38	81	57	119	79	94	147		168	62		114	33	46	43	87	140	86	26	131		
	0	1	0	0	0	0	0		0	0		0	0	0	0	0	1	0	0	1		
	0	36	0	0	0	0	0		0	0		0	0	0	0	0	50	0	0	50		
	1	17	0	12	3	10	19		17	4		10	8	4	3	4	20	12	4	22		
	60	100	0	143	95	138	179		287	57		166	42	50	84	93	167	128	24	179		
	2	4	2	5	3	4	5		6	4		6	6	4	3	3	7	3	2	5		
	110	22	83	55	87	50	43		93	52		91	29	45	31	64	53	29	11	37		
	0	0	0	0	0	0	0		0	0		0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0		0	0		0	0	0	0	0	0	0	0	0		
	2	5	1	5	2	4	4		3	3		2	4	3	4	3	5	1	1	3		
	249	61	94	124	132	114	78		105	88		69	44	77	95	146	87	22	12	51		
	0	1	0	1	0	2	2		2	0		2	2	1	0	1	2	1	1	3		
	0	18	0	37	0	84	57		103	0		102	32	38	0	72	51	33	18	74		
	2	18	1	11	5	8	17		11	8		10	7	8	3	7	24	10	8	22		
	106	93	40	115	139	97	140		163	100		145	33	87	30	143	176	93	41	158		
	0	2	1	1	2	2	2		2	2		2	2	2	1	1	2	2	0	2		
	0	70	270	72	378	164	112		201	170		198	62	147	68	140	99	127	0	97		
		10	0	11	4	9	17		13	4		7	8	5	3	3	22	11	8	22		
		35	0	77	74	73	94		129	33		68	25	36	20	41	108	69	28	105		
			0	3	2	2	3		2	2		1	3	1	1	1	3	1	0	3		
			0	162	286	124	127		152	129		74	72	56	51	106	113	49	0	110		
				5	4	7	13		10	7		7	8	6	5	5	10	9	3	15		
				71	150	114	145		200	118		138	50	88	68	138	99	114	21	145		
					1	4	5		3	5		4	2	3	2	2	8	4	4	6		
					100	174	149		160	224		209	33	117	72	146	210	134	74	154		
						1	12		9	4		8	5	5	2	3	7	7	3	15		
						19	155		208	78		182	36	85	31	96	80	102	24	169		
							2		13	8		10	7	6	5	6	22	11	3	27		
							18		205	107		156	35	69	53	131	172	110	17	206		
									1	3		11	8	6	3	4	16	9	4	15		
									28	72		307	71	124	57	156	224	161	39	206		
										15		4	7	2	3	2	10	4	4	8		
										302		94	52	35	49	65	118	60	33	92		
												1	6	4	1	6	10	8	3	13		
												27	52	82	19	231	138	140	29	175		
													2	4	3	3	11	6	3	9		
													6	26	18	37	48	34	9	39		
														0	3	4	6	3	1	6		
														0	42	115	62	39	7	60		
															1	2	5	2	1	2		
															13	53	47	24	7	19		
																1	6	3	1	6		
																54	116	74	14	114		
																	9	13	4	34		
																	62	115	19	230		
																		2	5	14		
																		23	31	121		
																			0	9		
																			0	43		
																				5		
																				33		
	3	57	6	31	13	17	38		31	45		19	29	9	10	11	76	27	16	58		

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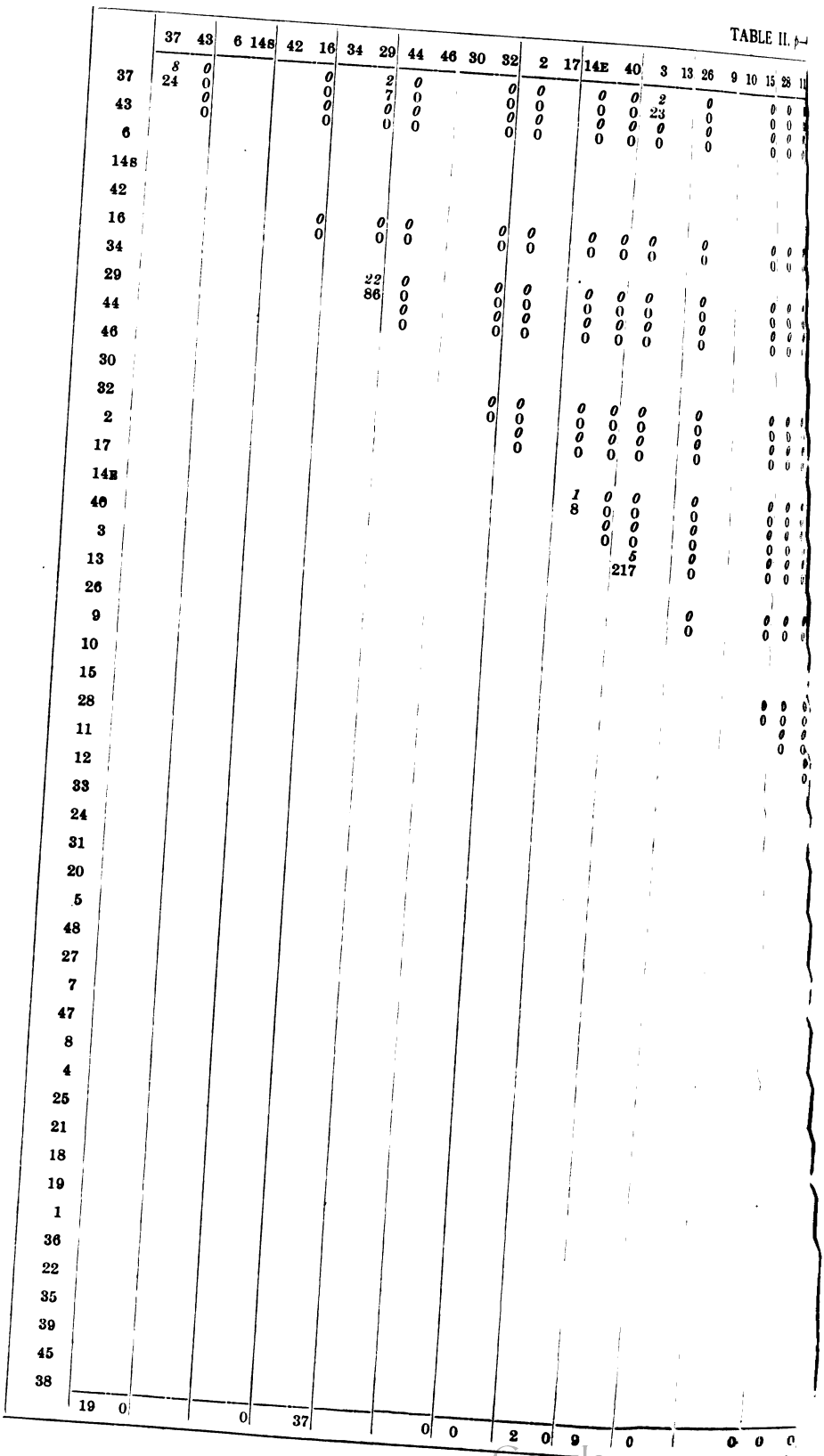
TABLE II.



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DECEMBER 16TH. N. = 34.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
	1	6	0	1	0	0	0	0	0	0	1	0	2	0		0	0	0	2	0	1	
	33	19	0	7	0	0	0	0	0	0	13	0	6	0		0	0	0	6	0	9	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	6	0	2	0	0	0	5	0	0	0	0	2	0		0	2	0	4	0	1	
	0	22	0	15	0	0	0	11	0	0	0	0	7	0		0	11	0	15	0	11	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	1	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	3	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	2	0	0	0	0	0	0	0	0	0	0		0	0	2	1	0	0	
	0	0	0	50	0	0	0	0	0	0	0	0	0	0		0	0	44	12	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	1	2	0	0	0	0	0	0	0	0	0	0	1	0		0	0	1	1	0	0	
	357	70	0	0	0	0	0	0	0	0	0	0	32	0		0	0	64	35	0	0	
		26	0	3	0	0	0	3	0	0	1	0	5	0		0	1	1	3	0	1	
		88	0	21	0	0	0	6	0	0	15	0	15	0		0	5	6	10	0	10	
			0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
				0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
				6	0	0	0	1	0	0	1	0	1	0		0	0	0	0	0	1	
				47	0	0	0	4	0	0	30	0	6	0		0	0	0	0	0	20	
					2	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
					200	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
						0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
							0	0	0	0	0	0	0	0		0	0	0	0	0	0	
								5	0	0	1	0	1	0		0	1	0	1	0	0	
								6	0	0	9	0	2	0		0	3	0	2	0	0	
									0	0	0	0	0	0		0	0	0	0	0	0	
										0	0	0	0	0		0	0	0	0	0	0	
											0	0	8	0		0	0	0	0	0	0	
												0	22	0		0	0	0	0	0	0	
														0		0	0	0	0	0	0	
																0	0	0	0	0	0	
																0	0	0	0	0	0	
																	0	0	2	0	0	
																		0	10	0	0	
																		5	0	0	0	
																		56	0	0	0	
																			12	0	0	
																			42	0	0	
																				0	0	
																					0	
																					10	
																					68	
	3	47	0	11	4	0	0	14	0	0	3	0	16	0		0	4	7	22	0	14	

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TABLE II.

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	22	11
37																								
43																								
6																								
148																								
42																								
16						*0*		*0*				*0*	*0*	*0*	*0*	*0*	*1*		*0*	*0*	*1*			
34						0		0				0	0	0	0	0	75		0	0	50			
29								*6*				*0*	*6*	*13*	*17*	*0*	*6*		*15*	*4*	*10*			
44								23				0	228	82	98	0	78		72	75	87			
46																								
30																								
32												*0*	*0*	*0*	*0*	*0*	*0*		*0*	*0*	*0*			
2												0	0	0	0	0	0		0	0	0			
17													*0*	*4*	*5*	*0*	*1*		*3*	*2*	*2*			
14E													0	243	280	0	127		141	366	169			
40														*0*	*12*	*0*	*4*		*13*	*5*	*4*			
3														0	111	0	83		101	151	55			
13															*4*	*0*	*4*		*16*	*4*	*8*			
26															34	0	77		114	111	102			
9																*0*	*0*		*0*	*0*	*0*			
10																0	0		0	0	0			
15																	*2*		*8*	*2*	*2*			
28																	87		128	125	58			
11																								
12																			*2*	*5*	*12*			
33																			12	116	128			
24																				*0*	*3*			
31																				0	126			
20																					*6*			
5																					118			
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
						3		36				0	6	15	32	0	15		32		24			13

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DECEMBER 23RD. N. = 25.

12 33	24 31	20 5	48 27	7 47	8 4	25 21	18 19	1 36	22 35	39 45	38
	0	*0* *0*	*0* *0*	*0*	*0*	*0*	*0* *0*	*0* *0*	*0*		
	0	0 0	0 0	0	0	0	0 0	0 0	0		
	16	*11* *6*	*21* *18*	*16*	*13*	*0*	*10* *5*	*10* *18*	*15*		
	59	82 119	181 106	168	115	0	77 36	146 94	100		
	0	*0* *0*	*0* *0*	*0*	*0*	*0*	*0* *0*	*0* *0*	*0*		
	0	0 0	0 0	0	0	0	0 0	0 0	0		
	5	*5* *4*	*6* *6*	*6*	*4*	*0*	*5* *1*	*4* 5	*4*		
	179	362 768	500 342	611	344	0	376 69	564 253	258		
	10	*9* *5*	*10* *11*	*13*	*10*	*0*	*8* *3*	*7* *11*	*6*		
	59	108 159	138 104	219	142	0	99 34	164 92	64		
	11	*12* *5*	*21* *18*	*12*	*14*	*0*	*14* *7*	*11* *17*	*14*		
	60	131 146	266 155	186	183	0	159 73	235 130	137		
	0	*0* *0*	*0* *0*	*0*	*0*	*0*	*0* *0*	*0* *0*	*0*		
	0	0 0	0 0	0	0	0	0 0	0 0	0		
	7	*4* *1*	*7* *3*	*3*	*3*	*1*	*4* *0*	*3* *5*	*3*		
	86	99 66	200 88	105	88	35	103 0	146 86	66		
	14	*11* *8*	*20* *14*	*16*	*11*	*1*	*13* *4*	*10* *14*	*9*		
	64	101 195	212 102	208	120	13	124 35	180 90	74		
	4	*5* *4*	*3* *5*	*5*	*4*	*0*	*4* *2*	*3* *4*	*3*		
	89	179 380	124 141	253	171	0	149 69	210 100	96		
	10	*7* *4*	*10* *10*	*8*	*4*	*1*	*7* *2*	*5* *7*	*5*		
	82	115 176	191 130	187	79	23	12 32	162 81	74		
	6	*6* *3*	*11* *7*	*7*	*5*	*0*	*9* *3*	*6* *9*	*5*		
	31	63 83	133 58	104	62	0	98 30	123 66	47		
	25	*9* *5*	*14* *16*	*15*	*11*	*0*	*8* *2*	*5* *12*	*7*		
	86	63 93	114 89	148	92	0	58 13	68 59	44		
		6 *5*	*13* *13*	*9*	*10*	*1*	*10* *5*	*9* *11*	*9*		
		85 188	213 145	180	168	20	147 68	249 109	114		
		7 *7*	*8*	*7*	*4*	*0*	*5* *2*	*6* *6*	*5*		
		700	305 238	372	179	0	196 72	441 158	168		
			2 *17*	*13*	*12*	*1*	*14* *7*	*9* *18*	*15*		
			38 219	301	234	23	238 110	288 206	219		
			5	*12*	*14*	*0*	*12* *5*	*8* *16*	*13*		
			44	189	187	0	139 54	175 125	129		
				0	*11*	*0*	*10* *3*	*9* *14*	*9*		
				0	262	0	208 57	352 196	161		
					2	*0*	*8* *4*	*6* *11*	*9*		
					40	0	140 65	198 130	136		
						1	*1* *0*	*0* *0*	*0*		
						27	20 0	0 0	0		
							2 *5*	*9* *11*	*6*		
							30 70	259 113	79		
							0 *4*	*8* *6*			
							0 106	76 73			
							0 *9*	*8*			
							0 174	198			
							4	*12*			
							28	106			
								4			
								45			
	56	22 19	31 29	19	20	2	17 8	14 28	25		

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	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	1
37																					1	16		
43			15	26									11				0				7	197		
6			44	98									363				0			0	1	7		
148				5									5		6		2			0	7	117		
42				32									211		42		34							
16																								
34																								
29																								
44																								
46																								
30																								
32														6	5	16	18	23		34	0.3	18		
2														2120	304	923	2285	1855		6205	28	2434		
17															8	6	4	1		3	1	6		
14E															77	56	76	14		75	9	128		
40																4	11	8		17	0.5	12		
3																34	217	100		484	7	242		
13																								
26																	8	24		14	1	11		
9																	336	679		877	40	533		
10																		3		24	0	27		
15																		46		960	0	812		
28																								
11																				0.4	0	15		
12																				34	0	1240		
33																					6	0.5		
24																					119	16		
31																						4		
20																						204		
5																								
48																								
27																								
7																								
47																								
8																								
4																								
25																								
21																								
18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
					67	46										32	24	30	31	32		25	13	35

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JULY 2ND—SEPTEMBER 24TH.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
				0						*8*			*45*			*27*						
				0						62			129			339						
1				*1*				*1*		*2*	*8*		*30*	*25*	*34*	*16*						
88				15				2		25	140		111	213	269	263						
11				*1*				*60*		*14*	*20*		*23*	*24*		*16*						
8456				241				1277		1227	3076		746	1853		2261						
2				*1*						*3*	*6*		*9*	*7*	*0*	*4*						
253				21						47	140		48	83	0	93						
3				*2*				*22*		*9*	*8*		*14*	*12*	*1*	*10*						
349				48				71		113	186		66	139	10	214						
6				*2*				*32*		*10*	*7*		*15*	*14*	*3*	*9*						
1474				109				231		296	360		167	374	84	437						
6				*2*				*39*		*17*	*10*		*25*	*23*		*19*						
1116				64				185		327	360		182	386		600						
7				*2*				*30*		*20*	*11*		*17*	*17*	*0*	*11*						
2481				190				316		867	817		273	618	0	769						
0				*0*				*0*		*1*	*0.3*		*3*	*1*	*2*	*1*						
0				0				0		25	12		21	17	32	45						
6				*1*				*57*		*13*	*9*		*18*	*18*	*1*	*13*						
1714				71				451		410	543		217	497	26	674						
0.4				*1*				*10*		*6*	*4*		*6*	*6*	*2*	*3*						
640				300				442		1017	1344		407	969	217	999						
				1				*3*		*1*	*1*		*2*	*2*	*2*	*1*						
				67				33		54	120		31	86	54	86						
								11		*40*	*14*		*26*	*27*	*1*	*22*						
								14		198	125		48	115	4	184						
										1	*11*		*14*	*17*	*0*	*10*						
										28	394		106	299	0	342						
											1		*12*	*12*	*3*	*9*						
											77		163	394	87	506						
													19	*37*	*22*	*23*						
													64	243	135	280						
														7	*21*	*20*						
														104	296	575						
															10	*10*						
															187	265						
																4						
																232						
9				5				60		26	19		82	56	40	39						

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TABLE II.

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28
	9	*7*	*23*		*3*	*6*	*16*	*19*	*3*	*5*	*14*	*2*	*1*	*7*	*19*	*1*	*6*		*27*		*11*	*7*	*4*
37	27	30	68		73	117	95	67	24	34	47	40	44	38	97	128	64		112		83	82	66
		7	*3*		*2*	*3*		*13*	*5*	*11*	*7*	*3*	*2*	*2*	*8*	*0.6*	*3*		*6*	*3*	*0.5*	*2*	*4*
43		44	13		71	88		67	67	114	37	86	90	137	60	155	51		38	74	5	32	56
			12		*0*	*2*		*15*	*5*		*25*	*2*	*8*	*6*	*15*	*0*	*4*		*14*	*3*	*9*	*12*	*1*
6			45		0	39		51	29		82	34	254	33	74	0	40		61	49	68	144	17
148																							
					0.2	*3*		*4*	*3*	*6*	*3*	*1*	*1*	*2*	*3*	*0.5*	*2*		*2*	*5*	*0.5*	*3*	*1*
42					63	542		126	263	379	75	159	306	219	127	79	209		91	757	35	340	270
						0.4	*10*	*5*	*0*	*6*	*9*	*2*	*0.5*	*5*	*6*	*0.5*	*2*		*6*	*1*	*4*	*2*	*1*
16						52	393	122	0	272	195	227	110	168	205	57	135		166	168	183	136	387
							1	*17*							*18*	*1*	*4*		*23*		*15*		*3*
34							12	116							180	340	91		194		227		168
								6	*6*	*12*	*18*	*2*	*3*	*18*	*18*	*0.3*	*5*		*21*	*5*	*11*	*7*	*4*
29								23	66	95	68	39	130	116	105	57	69		99	94	91	105	123
									1		*6*	*0*	*3*	*19*	*8*	*0*	*1*		*5*	*5*	*1*	*4*	*3*
44									31		63	0	357	335	124	0	37		72	265	24	145	90
										2	*17*	*9*	*2*	*14*	*5*	*2*	*9*		*19*		*3*	*4*	*12*
46										32	130	360	154	178	174	800	238		185		53	114	464
											4	*6*	*3*	*25*	*17*	*1*	*11*		*27*		*9*	*12*	*10*
30											15	105	110	152	97	190	139		126		76	164	185
												1	*0.5*	*5*	*3*	*0.2*	*1*		*3*	*0*	*0.3*	*1*	*1*
32												100	96	143	87	250	44		79	0	15	47	291
													0.4	*4*	*4*	*0*	*0.5*		*2*	*2*	*2*	*2*	*1*
2													138	256	210	0	73		102	365	190	320	240
														0.2	*15*	*0.2*	*4*		*14*	*6*	*2*	*6*	*7*
17														2	135	80	75		113	171	35	135	208
															1	*1*	*3*	0	*19*	*5*	*10*	*6*	*5*
14E															12	166	64	0	131	139	125	128	145
																0.1	*0.2*		*0.5*	*0*	*0.2*	*0.5*	*0.1*
40																1444	110		92	0	110	358	192
																	3	0	*6*	*2*	*3*	*1*	*3*
3																	164	0	99	104	79	55	189
																		0				0	
13																		0				0	
																			0.6	*4*	*14*	*7*	*4*
26																			4	100	155	122	189
																				0	*3*	*4*	*1*
9																				0	126	272	227
																					3	*3*	*5*
10																					54	105	198
																						2	*7*
15																						124	167
																							0.1
28																							40
11																							
12																							
33																							
24																							
31																							
20																							
5																							
48																							
27																							
7																							
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8																							
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21																							
18																							
19																							
1																							
36																							
22																							
35																							
39																							
45																							
38																							
	58	39	58		6	8	29	48	18	25	53	7	7	28	31	1	14		37	9	22	17	9

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OCTOBER 8TH—DECEMBER 23RD.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
0.5	3	16	2	8	4	8	18	35	7	11	1	14	25	16	17	8	11	15	38	30	5	27
35	109	52	56	50	60	60	89	67	68	85	13	122	71	108	108	95	52	85	123	136	48	116
1	1	8	2	6	2	3	10	3	7	4	4	5	12	6	5	3	16	6	8	10	2	3
103	33	40	67	56	52	37	78	7	101	46	83	62	50	56	49	65	109	55	40	68	26	16
4	4	22	1	10	5	29	12	28	14	6		6	23	9	19	10	27	10		11	10	15
253	130	70	24	65	80	218	59	243	128	49		54	66	61	118	122	122	58		49	89	63
1	0	2	0.5	1	2	1	3		0.5	1	2	2	3	3	2	2	2	0.5	4	2	1	0
636	0	67	114	80	278	92	142		42	215	254	188	79	202	100	234	62	27	118	68	82	0
0.5	3	5	1	2	1	0	5	9	0	3	0	5	7	5	6	3	0	2	6	5	2	8
228	537	106	204	103	114	0	182	107	0	164	0	285	142	213	226	235	0	6	126	147	88	222
1	6	15	3	10	2		20	22		12		16	24	17	15	8		6	18	18		11
138	390	96	148	130	69		205	84		186		289	138	229	187	203		69	16	160		92
0.5	3	18	2	11	3	11	20	31	12	8	4	12	22	15	16	9	18	5	26	19	7	15
39	93	132	69	86	62	96	117	69	126	73	63	130	72	116	117	138	93	91	94	95	72	67
2	0.5	4	1	4	2	4	9	3	2	2	2	3	8	2	8	4	5	3	6	4	2	2
333	53	38	106	84	129	85	149	18	59	42	89	78	71	116	150	164	78	47	57	62	58	27
		13	2	5	2	6	8			3		10	17	9	6	10				4	5	
		97	114	75	80	104	95			54		209	114	141	186	294				41	104	
0	3	19	1	10	3	18	13	26	14	5		10	19	12	16	14	24	10		10	10	12
0	108	68	27	72	47	145	73	55	142	43		95	61	86	110	187	120	64		52	125	56
0	0	1	1	2	1	1	2	3	0.3	0.2	0	1	3	1	2	1	0	1	0	1	1	4
0	0	28	95	56	75	44	59	28	18	11	0	53	55	49	84	92	0	11	0	34	52	98
2	0.3	2	1	3	2	1	3	6	2	2	2	1	5	3	3	3	3	1	1	1	0	1
1345	121	77	321	186	233	133	106	121	204	194	307	129	169	226	228	405	142	90	48	75	0	47
2	1	13	3	12	3	9	15		15	5	9	9	17	12	9	8	15	8	15	13	5	0
253	60	74	114	141	108	119	145		253	74	228	156	91	154	101	196	123	89	89	106	82	0
3	3	12	3	10	4	11	17	23	9	9	3	11	20	13	15	9	13	13	24	16	4	15
303	137	66	118	113	113	142	153	75	132	116	70	175	98	147	161	188	101	106	127	121	65	108
0	0	0.4	0	0	0.1	0.2	0.4	0.2		0.1	0	0.3	0.3	0.3	0.3	0.1		0	0.2	0.2	0.1	0
0	0	80	0	0	144	87	127	28	0	64	0	149	57	112	120	106	0	85	38	37	0	0
1	1	5	1	3	1	4	4	5	2	2	0.5	4	6	4	3	3	3	2	6	4	1	5
330	125	68	78	180	74	107	82	33	70	74	27	122	63	100	65	124	52	52	74	59	34	73
								0					0	0	0	0		0				
								0					0	0	0	0		0				
1	4	18	3	12	4	15	18	42	12	11	2	14	27	17	15	10	12	12	30	18	7	17
98	200	81	110	110	87	132	122	114	156	122	39	185	111	162	132	174	75	102	138	115	84	103
1		5	1	6	3	3	5		5	3	5	4	7	5	3	3	3	3	6	5		0
380		89	131	215	253	124	142		253	114	380	199	112	186	92	233	87	96	106	110		0
1	5	13	3	7	4	7	9	18	8	5		9	13	9	7	5	9	8	24	12	3	12
176	373	104	188	107	167	140	121	86	187	103		196	99	150	117	168	110	114	195	128	68	24
2	1	5	1	5	3	8	7	6	9	3	1	5	9	5	10	4	9	4	1	6	5	5
371	135	69	102	123	190	258	140	65	362	80	57	179	109	139	258	233	176	96	20	122	197	78
1	2	6	2	5	2	2	4	5	2	2	2	5	7	4	3	4	3	3	3	4	2	4
291	321	111	238	172	180	95	152	57	86	75	194	276	112	156	105	265	92	56	54	100	101	95
1	3	12	2	9	3	8	15	32	7	9	3	12	20	14	15	8	12	10	22	17	3	14
84	132	61	91	90	73	92	133	98	107	117	55	176	92	152	148	166	88	96	114	123	48	93
0	0.5	0.3	1	1	2	0	1	5	0	2	2	1	4	1	2	2	0.5	0.3	1	0.5	0	0
0	378	25	428	150	720	0	119	207	0	359	640	157	281	235	346	530	52	48	72	51	0	0
	0.2	4	1	3	1	1	3	3	1	2	0	3	4	3	2	1	1	2	2	3	0.5	3
	89	140	203	183	236	109	140	202	131	169	0	272	134	203	159	175	49	127	70	134	49	115
		12	3	9	3	11	8	29	11	7	1	9	18	10	10	6	13	10	14	13	6	13
		40	66	65	64	91	79	59	106	62	28	92	57	73	69	88	65	65	56	62	61	57
			0.1	3	1	1	2	4	1	2	2	2	3	3	2	2	2	1	3	2	1	1
			29	146	102	62	91	58	85	119	279	160	79	159	127	180	85	67	86	71	49	35
				5	3	7	11	17	6	6	3	8	13	9	9	7	7	7	11	10	2	10
				66	127	108	119	71	125	98	90	145	85	141	128	194	73	89	75	97	45	89
					2	3	3	6	3	2	0.5	2	5	2	3	3	4	2	2	3	1	3
					167	139	101	75	186	89	40	104	79	98	104	187	105	73	37	70	69	65
						2	11	15	10	5	0	4	8	8	11	7	16	10	1	8	6	13
						42	137	74	226	98	0	87	55	136	172	211	177	139	12	90	135	138
							2	28	10	10	5	11	23	14	15	8	15	11	23	18	5	13
							21	92	154	130	119	175	112	162	161	168	119	108	127	133	77	97
								5	8	20	1	23	30	21	23	9	14	15	53	33	8	40
								6	50	100	9	135	59	90	91	75	41	64	109	94	46	108
									0.5	5	0	5	7	7	8	6	12	6	2	9	4	8
									14	107	0	126	65	145	153	235	165	107	19	119	110	104
										2	1	7	12	7	7	4	6	7	14	8	1	13
										42	54	159	88	129	115	139	76	108	117	94	15	139
											2	2	6	3	5	1	2	0	3	2	0	0
											128	105	80	110	144	88	42	0	45	42	0	0
												0.5	15	10	8	6	5	7	15	7	2	11
												13	135	204	156	232	72	125	149	174	45	144
													9	16	20	9	13	11	33	19	5	20
													25	105	120	112	57	61	102	84	41	80
														1	12	10	9	7	21	13	5	14
														13	172	220	90	94	150	128	91	130
															4	8	15	7	20	15	7	10
															55	212	142	85	132	138	131	91
																0.2	7	5	6	6	5	5
																12	131	120	82	116	210	96
																	3	11	8	16	7	5
																	21	93	42	110	102	35
																		8	16	13	2	15
																		85	99	109	35	118
																			6	27	0	22
																			19	129	0	100
																				2	5	18
																				10	71	111
																					5	10
																					125	126
																						6
																						34
5	5	54	6	29	11	23	32	63	19	21	13	19	63	22	32	13	38	32	54	38	19	42

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TABLE II.—

	37	43	6	148	42	16	34	29	44	46	30	32	2	17	14E	40	3	13	26	9	10	15	28	11
	9	*7*	*23*		*3*	*6*	*16*	*19*	*3*	*5*	*14*	*2*	*1*	*7*	*19*	*1*	*6*		*27*		*11*	*7*	*4*	*14*
37	27	30	68		73	117	95	67	24	34	47	40	44	38	97	128	64		112		83	82	66	90
		7	*3*		*2*	*3*		*13*	*5*	*11*	*7*	*3*	*2*	*2*	*8*	*0.6*	*3*		*6*	*3*	*0.5*	*2*	*4*	*7*
43		44	13		71	88		67	67	114	37	86	90	137	60	155	51		38	74	5	32	56	58
			13	*26*	*0*	*2*		*15*	*5*		*25*	*2*	*9*	*6*	*15*	*0*	*2*		*14*	*3*	*6*	*13*	*1*	*11*
6			45	98	0	39		51	29		82	34	281	33	74	0	27		61	49	48	157	17	53
				5									*5*	*6*			*2*			*0*	*1*	*7*		
148				32									211	42			34			0	7	117		
					0.2	*3*		*4*	*3*	*6*	*3*	*1*	*1*	*2*	*3*	*0.5*	*2*		2	*5*	*0.5*	*3*	*2*	*3*
42					63	542		126	263	379	75	159	306	219	127	79	209		91	757	35	340	270	144
						0.4	*10*	*5*	*0*	*6*	*9*	*2*	*0.5*	*5*	*6*	*0.5*	*2*		*6*	*1*	*4*	*2*	*3*	*5*
16						52	393	22	0	272	195	227	110	168	205	57	135		166	108	183	136	387	171
							1	*17*							*18*	*1*	*4*		*23*		*15*		*5*	*17*
34							12	116							180	340	91		194		227		168	163
								6	*6*	*12*	*18*	*2*	*3*	*18*	*18*	*0.3*	*5*		*21*	*5*	*11*	*7*	*6*	*17*
29								23	66	95	68	39	130	116	105	57	69		99	94	91	105	123	93
									1		*6*	*0*	*3*	*19*	*8*	*0*	*1*		*5*	*5*	*1*	*4*	*2*	*4*
44									31		63	0	357	335	124	0	37		72	265	24	145	90	62
										2	*17*	*9*	*2*	*14*	*5*	*2*	*9*		*19*		*3*	*4*	*12*	*8*
46										32	130	360	154	178	174	800	238		185		53	114	164	89
											4	*6*	*3*	*25*	*17*	*1*	*11*		*27*		*9*	*12*	*10*	*14*
30											15	105	110	152	97	190	139		126		76	164	185	71
												10.5	*5*	*3*	*0.2*		*1*		*3*	*0*	*0.3*	*1*	*3*	*2*
32												100	96	143	87	250	44		79	0	15	47	291	49
													4	*4*	*6*	*0*	*7*	*23*	*2*	*15*	*1*	*8*	*1*	*2*
2													799	269	352	0	877	1855	1022	701	1211	1066	249	136
														3	*12*	*0.2*	*4*	*1*	*14*	*4*	*1*	*6*	*7*	*11*
17														30	112	80	75	14	113	133	19	132	208	101
															2	*1*	*5*	*6*	*19*	*10*	*7*	*9*	*5*	*15*
14E															18	166	102	67	131	277	91	162	145	124
																0.1	*0.2*		*0.5*	*0*	*0.2*	*0.5*	*0.2*	*0.3*
40																1444	110		92	0	110	358	162	80
																	5	*16*	*6*	*9*	*2*	*6*	*2*	*4*
3																	233	453	99	587	58	294	160	76
																		2		*24*		*18*		
13																		31		960		541		
																			0.6	*4*	*14*	*7*	*8*	*14*
26																			4	100	155	122	186	128
																				0.2	*1*	*13*	*3*	*5*
9																			23	31	917	277	88	
																				4	*2*	*5*	*5*	
10																				87	54	198	110	
																					3	*2*	*5*	
15																					161	167	107	
																						14	*4*	
28																						40	106	
																							3	
11																							*21*	
12																								
33																								
24																								
31																								
20																								
5																								
48																								
27																								
7																								
47																								
8																								
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18																								
19																								
1																								
36																								
22																								
35																								
39																								
45																								
38																								
	58	30	60	46	6	8	9	48	18	25	53	7	17	27	31	1	22	32	37	19	17	25	9	35

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JULY 2ND—DECEMBER 23RD.

12	33	24	31	20	5	48	27	7	47	8	4	25	21	18	19	1	36	22	35	39	45	38
0.5	3	16	2	8	4	8	18	35	7	11	1	14	25	16	17	8	11	15	38	30	5	27
35	109	52	56	50	60	60	89	67	68	85	13	122	71	108	108	95	52	85	123	136	48	116
1	1	8	2	6	2	3	10	3	7	4	4	5	12	6	5	3	16	6	8	10	2	3
103	33	40	67	56	52	37	78	7	101	46	83	62	50	56	49	65	109	55	40	68	26	16
4	4	22	1	10	4	29	12	28	14	7		6	29	9	19	14	27	10		11	10	15
253	130	70	24	65	60	218	59	243	128	52		54	82	61	118	176	122	58		49	89	63
1					1			1		2	8		30	25	34	16						
88					15			2		25	140		111	213	269	263						
1	0	2	0.5	1	2	1	3		0.5	1	2	2	3	3	2	2	2	0.5	4	2	1	0
636	0	67	114	89	278	92	142		42	215	254	188	79	202	100	234	62	27	118	68	82	0
0.5	3	5	1	2	1	0	5	9	0	3	0	5	7	5	6	3	0	2	6	5	2	8
228	537	106	204	103	114	0	182	107	0	164	0	285	142	213	226	235	0	76	126	147	88	222
1	6	15	3	10	2		20	22		12		16	24	17	15	8		6	18	18		11
138	390	96	148	130	69		205	84		186		289	138	229	187	203		69	116	160		92
0.5	3	18	2	11	3	11	20	31	12	8	4	12	22	15	16	9	18	5	26	19	7	15
39	93	132	69	86	62	96	117	69	126	73	63	130	72	116	117	138	93	91	94	95	72	67
2	0.5	4	1	4	2	4	9	3	2	2	2	3	8	2	8	4	5	3	6	4	2	2
333	53	38	106	84	129	85	149	18	59	42	89	78	71	116	150	164	78	47	57	62	58	27
		13	2	5	2	6	8			3		10	17	9	6	10				4	5	
		97	114	75	80	104	95			54		209	114	141	186	294				41	104	
0	3	19	1	10	3	18	13	26	14	5		10	19	12	16	14	24	10		10	10	12
0	108	68	27	72	47	145	73	55	142	43		95	61	86	110	187	120	64		52	125	56
0	0	1	1	2	1	1	2	3	0.3	0.2	0	1	3	1	2	1	0	1	0	1	1	4
0	0	28	95	56	75	44	59	28	18	11	0	53	55	49	84	92	0	11	0	34	52	98
5	0.3	2	1	3	2	1	3	19	2	6	6	1	12	10	3	7	3	1	1	1	0	1
5382	121	77	321	186	236	133	106	410	204	538	923	129	352	714	228	1024	142	90	48	75	0	47
2	1	13	3	12	2	9	15		15	4	7	9	14	10	7	7	15	8	15	13	5	0
254	60	74	114	141	75	119	145		253	64	169	156	73	127	84	157	123	89	89	106	82	0
3	3	12	3	10	3	11	17	23	9	9	6	11	18	13	14	9	13	13	24	16	4	15
320	137	66	118	113	97	142	153	75	132	115	140	175	90	145	154	194	101	106	127	121	65	108
0	0	0.4	0	0	0	0.1	0.2	0.4	0.2	0.2		0.0.1	0	0	0.3	0.3	0.3	0	3	0.1	0	0
0	0	80	0	0	144	87	127	28	0	64	0	149	57	112	120	106	0	85	38	37	0	0
4	1	5	1	3	1	4	4	14	4	5	5	4	10	8	3	5	3	2	6	4	1	5
965	125	68	78	180	90	107	82	99	70	159	265	122	112	380	69	261	52	52	74	59	34	73
6					2			20		17	10		17	15	0	13		0				
1116					64			93		327	360		121	257	0	400		0				
1	4	18	3	12	4	15	18	42	12	11	2	14	27	17	15	10	12	12	30	18	7	17
98	200	81	110	110	87	132	122	114	156	122	39	185	111	162	132	174	75	102	138	115	84	103
5		5	1	6	2	3	5	30	5	11	10	4	14	12	2	8	3	3	6	5		0
501		89	131	215	217	124	142	316	253	491	729	199	227	456	69	568	87	96	106	110		0
0.5	5	13	3	7	2	7	9	13	8	3	0.3	5	7	5	6	3	9	8	24	12	3	12
88	373	104	188	107	104	140	121	64	187	68	12	103	55	87	93	107	110	114	195	128	68	124
4	1	5	1	5	2	8	7	16	9	7	7	5	13	11	9	8	9	4	1	6	5	5
1042	135	69	102	123	139	258	140	162	362	230	381	179	159	302	225	437	176	96	20	122	197	78
1	2	6	2	5	2	2	4	5	2	2	2	5	7	4	3	4	3	3	3	4	2	4
291	321	111	238	172	180	95	152	57	86	75	194	276	112	156	105	265	92	56	54	100	101	95
1	3	12	2	9	3	8	15	32	7	9	3	12	20	14	15	8	12	10	22	17	3	14
84	132	61	91	90	73	92	133	98	107	117	55	176	92	152	148	166	88	96	114	124	48	93
0.2	0.5	0.3	1	1	1	0	1	7	0	4	3	1	5	4	2	3	0.5	0.3	1	0.5	0	0
320	378	25	428	150	533	0	119	301	0	606	1227	157	344	643	309	765	52	48	72	51	0	0
	0.2	4	1	3	1	1	3	3	1	2	0	3	4	3	2	1	1	2	2	3	0.5	3
	89	140	203	183	236	109	140	202	131	169	0	272	134	203	159	175	49	127	70	134	49	115
		12	3	9	3	11	8	29	11	7	1	9	18	10	10	6	13	10	14	13	6	13
		40	66	65	64	91	79	59	106	62	28	92	57	73	69	88	65	65	56	62	61	57
			0.1	3	1	1	2	4	1	2	2	2	3	3	2	2	2	1	3	2	1	1
			29	146	102	62	91	58	85	119	279	160	79	159	127	180	85	67	86	71	49	35
				5	3	7	11	17	6	6	3	8	13	9	9	7	7	7	11	10	2	10
				66	127	108	119	71	125	98	90	145	85	141	128	194	73	89	75	97	45	89
					1	3	3	4	3	2	1	2	4	3	3	2	4	2	2	3	1	3
					126	139	101	61	186	77	93	104	58	92	94	147	105	73	37	70	69	65
						2	11	15	10	5	0	4	8	8	11	7	16	10	1	8	6	13
						42	137	74	226	98	0	87	55	136	172	211	177	139	12	90	135	138
							2	28	10	10	5	11	23	14	15	8	15	11	23	18	5	13
							21	92	154	130	119	175	112	162	161	168	110	108	127	133	77	97
								7	8	24	10	23	30	23	18	13	14	15	53	33	8	40
								9	50	119	86	135	56	98	74	106	41	64	109	94	46	108
								0.5	5	6	0	5	7	7	8	6	12	6	2	9	4	8
								14		107	0	126	65	145	153	235	165	107	19	119	110	104
										2	7	7	13	11	6	6	6	7	14	8	1	13
										37	258	159	95	185	103	211	76	108	117	94	15	139
											1	2	10	10	4	7	2	0	3	2	0	0
											91	105	140	313	106	387	42	0	45	42	0	0
												0.5	15	10	8	6	5	7	15	7	2	11
												13	135	204	156	232	72	125	149	174	45	144
													13	25	20	15	13	11	33	19	5	20
													42	164	123	185	57	61	102	84	41	80
														3	14	13	9	7	21	13	5	14
														43	197	362	90	94	150	128	91	130
															5	8	15	7	20	15	7	10
															79	222	142	85	132	138	131	91
																2	7	5	6	6	5	5
																108	131	120	82	116	210	96
																	3	11	8	16	7	5
																	21	93	42	110	102	35
																		8	16	13	2	15
																		85	99	109	35	118
																			6	27	0	22
																			19	129	0	100
																				2	5	18
																				10	71	111
																					5	10
																					125	126
																						6
																						34
7	5	54	6	29	8	23	32	62	19	23	17	19	71	36	34	24	38	32	54	38	19	42

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TABLE III.—Locations of Sources of Atmospherics, etc. (*see p.* 9).

1	2	3	4	5	6	7	8
July 2 2030	20 21 D.A. 30° S 5° E S Atlantic.	18 19 22 D.A. S Atlantic.	180 190	190	No details.	15	——
July 9 2030	20 21 D.A. 45° N 35° E Black Sea. 14° N 20° E Central Africa.	18 D.A. 45° N 35° E Black Sea. 19 22 23 D.A. Black Sea and Central Africa.	160 165 85 95	90	No details.	100	Oxford-Eskdalemuir, 91-90-47. Streatley-Huddersfield, 101-106-57. Streatley-Norfolk, 101-101-69. Windsor-Matlock, 115-97-74.
July 16 2030	20 21 D.A. 38° N 53° E Caspian.	18 D.A. 37° N 33° E Black Sea. 19 D.A. 37° N 33° E Black Sea 40° N 48° E Caspian. 22 23 D.A. 35° N 57° E Caspian.	165 85	82	Cold front moving S, with thunder-storms over Central Europe.	45	Petersfield-Darlington, 27-42-17. Windsor-Huddersfield, 90-38-20. Felixstowe-Huddersfield, 8-38-7.
July 23 2030	20 21 D.A. 10° N 10° E Equatorial Africa.	18 19 D.A. 52° N 30° E 22 23 D.A. Equatorial Africa.	160 165 80	90	No details.	40	——
Aug. 13 2030	20 21 D.A. No fix. D Chart suggests near sources.	18 19 D.A. No fix. 22 23 D.A. 30° N 90° E	—	—	——	60	Oxford-Pitlochry, 72-62-25. Oxford-Windsor, 72-145-52. Streatley-Pitlochry, 151-62-50. Streatley-Felixstowe, 151-4-4.

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Sept. 17 2030	20 21 A.L. 5° S 30° W Off NE Brazil.	18 19 22 A.L. Off NE. Brazil. 23 A.L. 10° S 43° W Brazil.	No Record	—	No details.	20	Norfolk-Streatley, 20-24-6.
Sept. 24 2030	20 21 D.A.L. No. fix. D.L. Charts suggest near sources.	18 19 22 23 D.A.L. No fix.	—	—	——	50	Oxford-Aberdeen, 44-67-27. Oxford-Windsor, 44-123-36. Aberdeen-Windsor, 67-123-45. Pitlochry-Windsor, 53-123-41.
Oct. 8 2130	21 22 D.A.L. 33° N 5° E Algeria. 18° N 7° E Sahara. 22 D.A.L. 27° N 40° W Atlantic.	19 20 23 24 D.A.L. 33° N 5° E 19 20 D.A.L. 18° N 7° E 23 D.A.L. 23° N 3° E and 27° N 40° W	172-174 172-174 246	170 250	Shallow trough N to S from England to Algeria. Depression Atlantic Centred 30°N 30° W	50	Oxford-Windsor, 22-147-22. Aberdeen-Windsor, 52-147-43. Norfolk-Windsor, 42-147-34. Falmouth-Windsor, 41-147-36. Falmouth-Aberdeen, 41-52-22. Felixstowe-Aberdeen, 17-52-11.
Oct. 15 2130	21 22 D.A.L. 25° S 85° W E Pacific.	19 D.A.L. 65° N 170° E NE Siberia. 20 D.A.L. 70° N 140° E NE Siberia. and 30° S 90° W SE Pacific and 23 D.A.L. nil.	248-252	240	No details.	10	——
Oct. 27 2130	21 22 D.A.L. 30°N 30° W SW from Azores.	19 20 24 D.A.L. No fix. 23 D.A.L. SW for Azores.	240 242	240	Cold front running NE–SW passed the Azores at 18h.	35	Murcia-Donegal, 32-33-16. Murcia-Darlington, 32-33-17. Murcia-Wallingford, 32-40-19. Paris-Darlington, 37-33-15. Oxford-Aberdeen, 16-63-11.

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TABLE III.—Locations of Sources of Atmospherics, etc. (*see p. 9*).—*Continued.*

1	2	3	4	5	6	7	8
Nov. 3 2130	21 D.A.L. 40° N 10° W W from Portugal. 22 D.A.L. No fix. (Unfavourable relations to L.D. Base.)	19 D.A.L. No fix. 20 D.A.L. 42° N 7° W N from Spain. 17h 45° N 4° E	218	No Obs.	Occluded depression centred Rochefort 2y front extending SW from centre. Thunderstorms 18h Marseilles district.	65	Murcia-Windsor, 33-78-30. Murcia-Potsdam, 33-34-14. Pyrenees-Windsor, 47-78-42. Pyrenees-Lerwick, 47-49-16. Pyrenees-Bergen, 47-81-26. Pyrenees-Funchal, 47-5-3. Pyrenees-Potsdam, 47-34-20. Potsdam-Windsor, 34-78-23. Funchal-Cork, 5-57-3. Funchal-Windsor, 5-78-3.
Nov. 10 1915	19 D.A.L. 40° N 10° W W from Portugal. 20 D.A.L. 38° N 12° W	17 18 21 D.A.L. W from Portugal.	214	210	Extensive occluded depression stationary Valencia-Madeira. Thunderstorm Oporto 0700 on 11th.	40	Fez-Lerwick, 8-29-5. Fez-Donegal, 8-24-5. Murcia-Conway, 7-41-6. St. Bees-Oxford, 39-16-16. Conway-Kew, 41-18-17.
Nov. 18 1915	19 D.A. 42° N 13° E Near Rome.	17 D.A. 43° N 10° E 18 D.A. 39° N 16° E 22 23 24 D.A. 45° N 10° W	131 253	130 253	Thunderstorm Rome 18h. Cold front, with indications of thunderstorm activity over Bay of Biscay.	100	Murcia-Bergen, 108-114-104. Funchal-Falmouth, 55-170-53. Pyrenees-Windsor, 130-145-87. Pyrenees-Falmouth, 130-170-105. Paris-Falmouth, 61-170-50. Bergen-Conway, 114-119-78.
Nov. 25 1915	19 D.A.L. No fix. L. and C.R.D.F. supported by A, give 60° N 20° W 20 D.A.L. 5° N 40° W	17 D.A.L. No fix. 18 D.A.L. 58° N 15° E S Sweden. 21 D.A.L. 4° S 50° W	—	310	—	50	Funchal-Bergen, 65-57-15. Funchal-Aberdeen, 65-58-15. Funchal-Falmouth, 65-87-27. Fez-Bergen, 36-57-12. Fez-Hereford, 36-78-16. Murcia-Conway, 29-40-19.

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	Atlantic doldrums.	N Brazil. 22 D.A.L. Atlantic doldrums	230	237	No details.		Murcia-Norfolk, 29-32-19. Murcia-Wallingford, 29-50-20. Murcia-Bergen, 29-57-16. Potsdam-Pembroke, 48-43-37. Potsdam-Wallingford, 48-50-36.
Dec. 9 1915	19 A.L. No fix. 20 A.L. 58° N 35° E SE from Leningrad.	17 18 A.L. No fix. 21 22 A.L. SE from Leningrad.	—	40–60 130	No details. Cold front Tripoli to Cyprus.	60	Murcia-Lerwick, 58-104-38. Murcia-Potsdam, 58-76-34. Murcia-Donegal, 58-53-26. Pyrenees-Lerwick, 16-104-9. Pyrenees-Donegal, 16-53-7. Pyrenees-Bury St. Edmunds, 16-61-8. Pyrenees-Hereford, 16-57-8. Potsdam-Lerwick, 76-104-50.
Dec. 16 1915	19 D.A.L. 64° N 45° E (near Archangel). 20 D.A.L. 65° N 60° E (North Urals).	17 18 D.A.L. 64° N 45° E 21 22 D.A.L. No fix.	44	40	Occluded depression centred SE of Archangel, with extensive snow.	5	——
Dec. 23 1915	19 20 D.A.L. No point fix, but data indicate line source. 65° N 40° E to 50° N 40° E	17 18 D.A.L. 65° N 40° E (White Sea). 21 22 D.A.L. No fix.	50	50—90 150	Cold front 70° N 60° E to 60° N 35° E Cold front Sardinia to Algeria.	35	Paris-Donegal, 25-36-15. Paris-Darlington, 25-32-14. Paris-Pembroke, 25-31-15. Paris-Cork, 25-29-13. Potsdam-Donegal, 28-36-18. Potsdam-Darlington, 28-32-17. Oxford-Donegal, 14-36-10. Wallingford-Potsdam, 8-28-8. Wallingford-Paris, 8-25-6.

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TABLE IVA.—SIMULTANEOUS REPORTS OF OUTSTANDING INTENSITIES.

Oct.	27th.	14, 24, 39; 17, 19, 21, 25; 21, 39.
Nov.	3rd.	14, 21; 14, 21; 28, 39; 14, 21.
,,	10th.	3, 11, 14, 17, 25, 29, 46; 14, 16; 11, 14, 16, 18, 19, 20, 21, 25, 26, 28, 29, 30, 32, 42; 14, 16; 14, 16, 32, 37; 14, 10, 37, 43; 10, 14, 32; 20, 26; 14, 16, 25; 14, 39; 3, 26; 20, 26, 28; 10, 45, 46; 16, 39; 14, 16, 21, 37, 43; 21, 32; 14, 21, 42; 21, 37.
,,	18th.	14, 21, 38; 14, 38, 39; 25, 37, 38, 39; 26, 37; 11, 14, 21, 39; 38, 39; 14, 21; 14, 25, 38; 14, 16, 21, 26; 14, 25, 38, 39; 25, 26, 37; 14, 26, 37, 38, 39; 10, 14, 21, 25, 37, 38; 20, 26, 37, 39; 20, 21, 25, 37, 38, 39; 14, 37; 37, 39; 18, 39; 14, 16, 21, 25, 26, 28, 37, 38, 39; 14, 16, 21, 26, 33, 37; 11, 14, 18, 20, 21, 25, 26, 37; 21, 37, 38; 11, 14, 37, 38; 21, 37, 38; 27, 37; 37, 39; 37, 38; 16, 26, 37; 14, 37; 14, 16, 24; 11, 14, 16, 21, 37; 21, 26; 21, 38; 14, 21; 21, 37; 21, 37, 38; 21, 38; 21, 31; 21, 37; 20, 21; 21, 37.
,,	25th.	1, 39, 45; 20, 26, 37, 39; 14, 24; 14, 36; 22, 37, 38, 39; 36, 45; 6, 14, 20, 22, 26, 37, 45, 48; 14, 21, 37; 37, 45; 6, 37; 24, 30; 6, 15, 21, 37, 39, 48; 21, 39; 21, 45; 14, 21, 37; 5, 21, 39.
Dec.	9th.	14, 25; 29, 36; 14, 20, 36, 43; 11, 21, 22, 47; 36, 43; 22, 36, 43; 36, 43; 39, 43, 47; 20, 39; 21, 36.
,,	23rd.	14, 26; 3, 36; 5, 14, 36; 14, 20, 36.

TABLE IVB.—SIMULTANEOUS REPORTS OF MULTIPLE DISTURBANCES.

Oct.	27th.	20 and Ditton Park; 17, 21, 26, 39.
Nov.	10th.	21, 24, 26; 11, 18, 24, 26, 29, 46; 21, 26, 29, 32; 21, 26; 24, 26; 17, 25, 26.
,,	18th.	18, 21, 26, 37; 21, 26; 16, 29.
,,	25th.	24, 30, 39; 24, 30.
Dec.	9th.	21, 43.
,,	23rd.	22, 36, 47.

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(2)	*La Nature, Paris.*	41 (1)	1913	218
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(18)	,, ,, ,, ,,	111A	1926	615
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DISCUSSION.

The Report has been prepared by a Committee of the Society consisting of Messrs. C. J. P. Cave, D. Brunt, M. A. Giblett and R. A. Watson Watt (convener). It was read at an ordinary meeting of the Society held in the Society's Rooms on April 20th, 1927. Invitations to attend the meeting had been extended to the members of the Physical Society and others interested in the subject. Amongst those taking part in the discussion were Admiral of the Fleet Sir Henry Jackson, G.C.B., K.C.V.O., F.R.S., Chairman of the Radio Research Board; Lieut.-Colonel A. G. Lee, O.B.E., M.C., Staff Engineer, Post Office; Captain A. G. D. West, M.A., B.Sc., Chief Research Engineer, British Broadcasting Corporation; Captain J. A. Slee, C.B.E., R.N. (Retd.), Marconi International Marine Company; T. L. Eckersley, Esq., B.A., B.Sc., Marconi Wireless Telegraph Company; O. F. Brown, Esq., M.A., B.Sc., Secretary Radio Research Board. J. F. Herd, Esq., A.M.I.E.E., M.I.Rad.E., Radio Research Station; Captain R. Bureau, Head of the Transmission Section of the Office National Météorologique, Paris.

A summary of the discussion is appended.

Mr. R. A. Watson Watt, in presenting the report, remarked that it would be clear that the short title of the paper ought, to avoid misinterpretation, to be expanded to read "The normal distance from its source at which a normal atmospheric produces in a normal broadcast receiver a sound estimated by a normal observer of normal aural acuity to be comparable in intensity with normal broadcast matter from a normal transmitter situated at such a distance from the receiver as to give normally satisfactory broadcast reception."

Sir Henry Jackson congratulated the Committee on their work in organizing and carrying out the work and analyzing it, and on the satisfactory results they had obtained, and considered that they had proved their statements as to the long distance at which some atmospherics could be received in the examples described by Mr. Watson Watt in his lecture.

The paper showed the difficulties they had to surmount in their work, and what they had to guard against, such as two simultaneous atmospherics occurring at different places, the variation in the sensitiveness of the receiving sets, and the personal error of different observers.

He hoped the observations would be continued with any modifications in the work that their recent experience showed to be desirable.

Lieut.-Colonel A. G. Lee: The possibility of locating meteorological disturbances by observations on wireless atmospherics demands that the atmospherics observed shall be gathered from the same area which is covered by the meteorological observation network, and it is therefore of the greatest importance that the question of the range of wireless atmospherics should be settled. As has been pointed out by Mr. Watson Watt, there is a very wide divergence of views on this point, and I should like, therefore, to congratulate the Committee upon the excellent work done in this paper. The results obtained should, however, only be regarded as a preliminary and there is no doubt that considerable further work will be necessary before all the meteorological authorities in different parts of the world are convinced on the subject of range. The Committee have been wise in confining their preliminary efforts to the settlement of this point. While a certain amount of correlation between atmospherics and meteorological observations has been shown in the

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paper, this has not been their main object, and the correlation work will no doubt demand a very considerable series of experiments after the range question has been settled. The French wireless engineers, in particular, seem to be fully convinced of the short range nature of wireless atmospherics. When there is such a wide divergence of views as exists between the French engineers and those of other countries it is desirable that attempts should be made to bridge the gap between the two schools of thought. One method of doing this is for each side to try the experimental methods of the opposite party. I was pleased to note in this connection, in the list of observers, the name of Captain Bureau of France.

I have been associated, to some extent, with some of the tests on which the American Telephone and Telegraph Company based their opinion on the range of atmospherics given in Reference 28, and it may be of interest to describe how the measurements on atmospherics were made. The receiver was tuned with a band width of 2,500 cycles. An artificial signal superimposed on the atmospherics received by the apparatus was adjusted in strength until the sound of the signal was just drowned by the noise of the atmospherics. In this process the signal is not drowned by the louder clicks which occur only occasionally. It is probable that these louder clicks, being quite distinct and separate, come from comparatively near distances and that the ground work of noise which drowns the signal consists of a large number of clicks gathered from much longer distances. The method, therefore, may be said to observe only the long distance atmospherics and ignore the shorter distance ones.

If the atmospherics come from short distances as stated by the French engineers, it would be expected that they would give a uniform distribution in azimuth. Now our experience with commercial directional reception indicates that in this country atmospherics are more or less concentrated round a mean south-easterly direction while the north-westerly direction is comparatively clear of atmospherics. Similarly, in America they find that the direction towards England is comparatively clear of atmospherics and that the opposite direction, south-westerly, is the point from which maximum atmospheric disturbances arrive. It is therefore fairly clear that the atmospherics which disturb long distance commercial reception are not of short distance origin, seeing that the distribution in azimuth is not uniform.

Captain A. G. D. WEST: The problem of "Atmospherics and the Weather" has always been a difficult one to tackle. It is similar to the problem of "Wireless and the Weather," a subject about which no two people have the same opinion.

The reason is that these subjects are much more comprehensive than would appear at first sight; in other words, there are many variables, which when observed under widely differing conditions give correspondingly widely different results, and may in many cases lead to directly opposite conclusions.

We have seen how opinions on the range of atmospherics can be so different. This is due undoubtedly to the difficulty of moulding into a complete whole the relations between the variables so as to be able to correlate results with a given set of conditions. In the subject under discussion the variables include such things as the type of initial electrical disturbance, the degree of ionization of the atmosphere, the distance of the receiving point from the source, the wave-length of reception, the

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selectivity of the receiver, and the response of the receiving system with regard to direction of reception and the plane of polarization of incoming waves.

An example of what seems to be a result difficult to explain is shown in Table I. One would expect that in averaging up, the greater the distance from the transmitting station, the greater the disturbance from atmospherics, independently of the type of receiving set used, provided that the aerial were of the normal type used by broadcast listeners. But an examination of the table shows for instance in the case of reception from London, No. 21 observer near Windsor heard an average number of 59.9 atmospherics, No. 2 at Dumfries, an average of 5.2, and No. 6 at Aberdeen an average of 58.0. Is the explanation for this to be found in some curious aural effect? I have often observed that the relative strength of an atmospheric background to long distance reception depends on the strength to the ear; when reception of the music is weakened sufficiently the background may almost disappear in falling to an acoustic strength comparable with the threshold of audition, or possibly because of some masking effect.

The authors are to be congratulated on their paper, and in particular for attacking the problem so thoroughly; on the competency of their observers; and on their good fortune in being able to combine so effectively so many simultaneous observations.

The British Broadcasting Corporation are pleased that their transmissions have proved to be such an effective time base for the purpose.

Captain J. A. Slee, R.N., expressed his admiration of the method adopted for the synchronizing of the observations. He felt, however, for two reasons, that the evidence was not fully conclusive.

In the first place the observations had only been taken for a period of about ten minutes and on a very limited number of occasions, and secondly most of them had been taken in Great Britain which is a country fortunately free of atmospherics and during the time of year when atmospherics are still more rare, and the rest in Australia, a country which is still more fortunate in this respect.

Further, those who have listened to wireless signals all over the world are agreed that there are many places, notably the Mediterranean, Indian Ocean and the neighbourhood of New York, where atmospherics are loud and practically continuous throughout the greater part of the 24 hours, especially in the summer season, and that if the working of ships in the Mediterranean is listened to at night during the summer, it is quite common to hear constant requests for repetition due to atmospherics, although the atmospherics themselves are quite inaudible in England.

Further, on the same subject, evidence has been obtained that on some occasions the centre of a revolving storm appears to coincide with the bearing of minimum atmospherics.

Considering all the above, he did not think that there was definite proof that anything but a very small percentage of the atmospherics likely to be heard under seagoing conditions were, in fact, of very long range, although he would not suggest that a large percentage of those heard by an inland broadcast receiver in England were not of long range. It is common for one coast station to be in great difficulty with atmospherics while another coast station not far from it or receiving stations further inland are hardly troubled at all.

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Mr. T. L. Eckersley sketched the evidence for long reception ranges of atmospherics referred to in reference No. 27 of the bibliography. He pointed out, however, that the effective range was a function of the wave-length on which reception was effected, and depended also on the conditions of insolation along the path. He referred to the distribution of the energy content of atmospherics in the frequency spectrum, and said that the reduction of energy content of the atmospheric distribution on proceeding from 30 metres to 15 metres must be of the order of one-thousandfold. Some of the divergences of opinion referred to in the paper, in particular the differences between Bureau's estimates and those now reached by the Committee, might be due to differences in the wave-lengths used and to the difference between day and night conditions. He suggested that in meteorological applications of observations on atmospherics the wave-length should be chosen to give the range of reception desired. He estimated at 200 kilometres the effective daylight range of reception of atmospherics on about 200 metres wave-length.

Sir Napier Shaw said that the present report marked the beginning, not the end, of an investigation. Meteorological researches usually began by dealing with normals, as in this case, but the study of maxima and minima was desirable as a further stage. To take the question of minima, was there any part of the world—Spitsbergen perhaps—which was free from atmospherics on the occasions studied? He asked whether the term "cold front" in the paper referred to that particular portion of the generally continuous polar front which it had been customary in earlier discussions of the Norwegian theory to call the "squall line."

Mr. O. F. Brown said that in his experience of reception in Singapore there had been many cases in which nearly continuous lightning was visible at the receiving station, while the reception of traffic remained quite satisfactory. Turning to the numerical data in the report he inquired whether the Committee could offer any estimate of the probability of random coincidences due to the simultaneous reception of two independent atmospherics at different stations.

Mr. J. F. Herd: Both the Society and the Committee concerned are greatly to be congratulated on this report, which forms a very notable contribution to the literature of atmospherics.

Work on the instantaneous and simultaneous observation of atmospherics is always difficult, and the system used here has given a remarkable volume of quantitative data from a method not, of itself, highly quantitative. The extraction of the information so neatly presented has entailed a large amount of labour, and has undoubtedly been done in a most skilful and thorough manner.

The large number of coincidences noted in Column 8 of Table III. is very remarkable, and greatly exceeds the highest expectations that one could have entertained in advance. The case shown for Murcia-Bergen on November 18 is particularly striking.

The evidence of the paper in conjunction with other available evidence would point to the limits of range suggested as being by way of a lower rather than a higher limit.

In common with other speakers, I would hope that similar work may be arranged on an even wider scale of observers and on as many different wave-lengths as may be practicable. In such future work it is also to be hoped that the co-operation of two cathode-ray direction-

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finding stations may be possible, with the view of locating actual instantaneous sources.

Dr. G. C. SIMPSON said that he was much struck by the thoroughness of the investigation and the large amount of computing which had been carried through. He congratulated Mr. Watson Watt and his associates on their success.

The fundamental object of the inquiry was to discover the origin of atmospherics; but he was not sure that that end had been attained.

We all know that a lightning discharge produces an electro-magnetic disturbance which is obviously one form of atmospheric; but do we know that all atmospherics are due to lightning discharge? There are many indications in the paper that the radio disturbances sent out by known thunderstorms are only local. What we really require is to be able to plot out the region affected by a lightning discharge which was actually observed. That, however, would be a difficult problem, and was outside the range of this investigation.

Dr. Simpson said that he was not convinced that actual thunderstorms were the only source of atmospherics. He knew from his own observations in the Antarctic that drifting snow can produce large electrical effects, and it was not impossible that high up in the atmosphere there may be regions filled with ice crystals where similar electrical effects would be produced. Small discharges, different in character from ordinary lightning discharge, might in this way be the cause of many atmospherics.

Dr. C. CHREE remarked that the National Committee on Geodesy and Geophysics had proposed as a subject for discussion by the section of Terrestrial Magnetism and Electricity, at the meeting next September at Prague, the institution of an international programme for recording lightning. Some definite proposal should be prepared for the support of the British delegates to the meeting.

He also inquired whether any association of atmospherics with aurora or magnetic disturbance had been observed on the occasions discussed by Mr. Watson Watt.

Mr. D. BRUNT said, with reference to Captain Slee's remarks on tropical revolving storms, that Father Gherzi had reported the non-radiation of atmospherics from typhoons in Chinese waters, and had interpreted this result as supporting the view that these typhoons were structures in which polar air did not intervene. The observations mentioned by Captain Slee were not, therefore, in contradiction of the general hypothesis of a frontal origin for atmospherics.

Captain R. BUREAU (Observer No. 22) (communicated): One must be very grateful to the Committee of the Royal Meteorological Society for the new work which they have just completed and which has for its object the presentation of supplementary experimental results on the range of atmospherics. My present conclusions on this subject diverge widely from those generally expressed in England and from the conclusions of this report. Does this mean that our points of view are diametrically opposed? I do not at all think so. Atmospherics are a multiple and complex phenomenon and their study may be approached by very different experimental routes. It happens that one method of approach gives indications of long range effects—and perhaps also gives apparent indications of long range effects—while other methods reveal short range effects. Some very recent experiments have enabled me to

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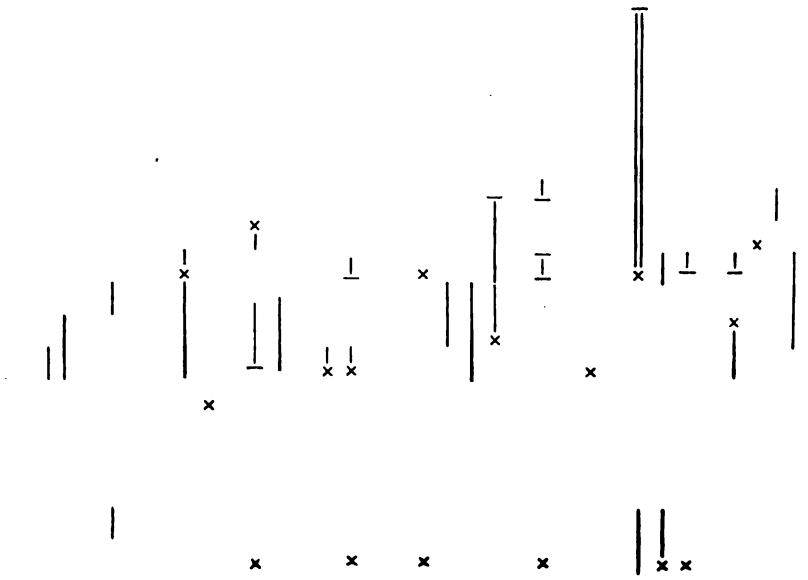
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 34 35 36 37 38 39 42 43 44

Typical Semi-Graphic Table of Incidence of Disturbance.

In the column headed by the identification number of each observer is inserted a line whose position and length indicate, on a vertical time scale, the incidence and duration of the disturbances reported by him. Crosses represent disturbances falling in spaces between words, transverse marks show disturbances beginning or ending between the syllables of a word. Double lines represent heavy disturbances. The matter covered by this sheet occupied about forty-five seconds in delivery.



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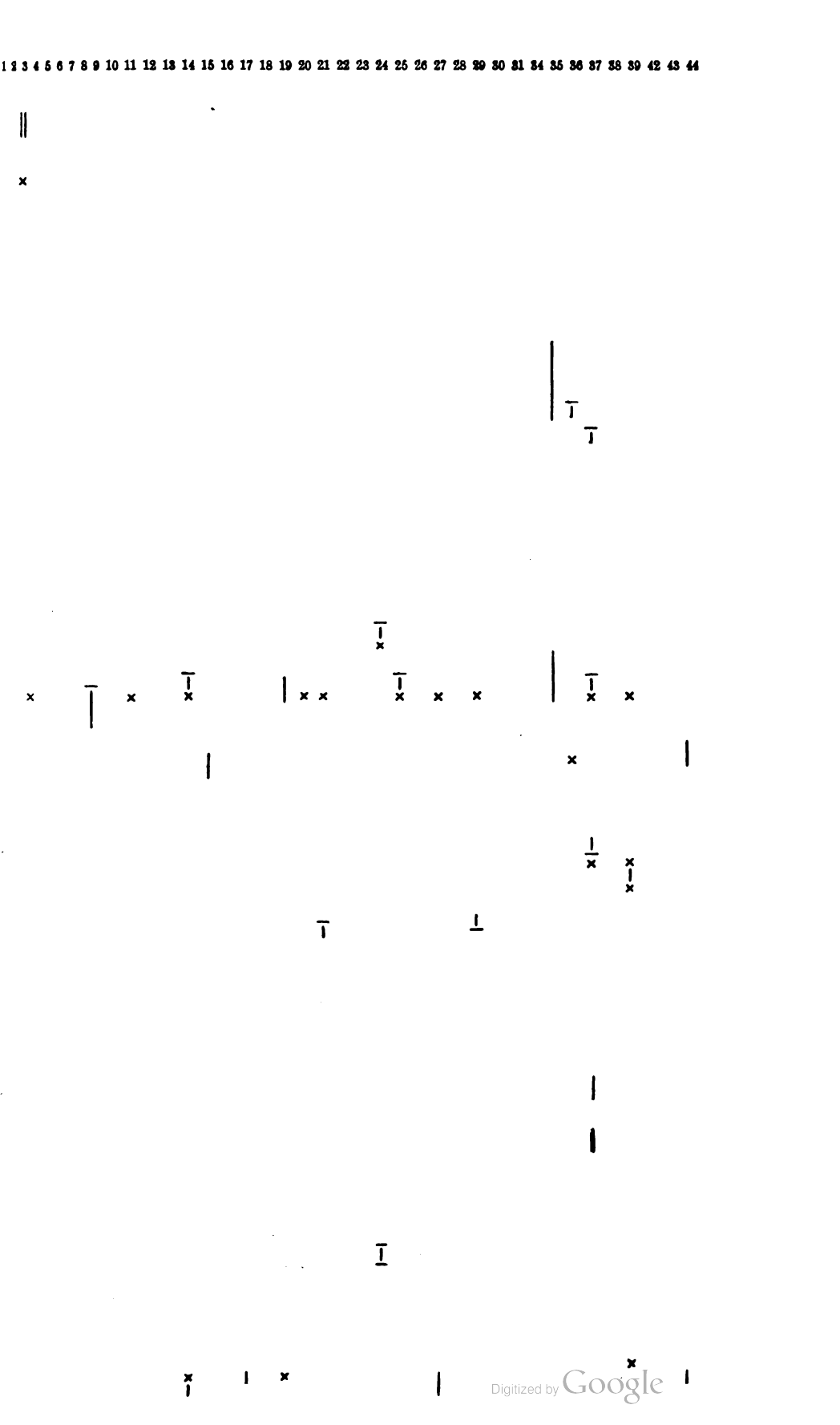

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show these latter in a particularly striking manner. I give herewith some examples of the results obtained. As for effects at great distances, these may at times be apparent only. It may in fact happen that telegraphic or telephonic wireless transmitters are modulated in some way by local atmospherics and that in effect the transmitter relays these atmospherics. We have sometimes observed in France that atmospherics heard during the reception of a particular transmission ceased at the same time as the transmission, or, again, were not found on adjacent wave-lengths. It is possible that such phenomena increased the percentage of simultaneous atmospherics received at distant stations.

There are reproduced herewith (Figs. 1 and 2) some records taken at Paris showing the rapidity with which atmospherics follow one another (*i.e.*, the frequency of incidence of atmospherics).

The first record was taken on the night of one of the experiments organized by the Committee of the Royal Meteorological Society, the night of the 8th to 9th October, 1926. The recording of atmospherics was carried out at Mont-Valérien near Paris on a wave-length of 1,600 metres. This record forms the lower trace. The two upper curves give the records of speed and direction of wind at the top of the Eiffel Tower.

Three sharply differentiated régimes of atmospherics correspond (with a time difference of 40 minutes representing the time of propagation of the meteorological phenomena from Mont-Valérien to the Eiffel Tower) to the passage of three different air masses. A very violent and brief recrudescence of atmospherics occurred at 2.30 and corresponded to the replacement of one air mass by another.

Fig. 2 gives two other examples. The atmospherics (upper trace) are due to the instability of polar air. This instability is also revealed in the turbulence of the wind whose velocity is shown by the lower trace

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in each figure. There is absolute parallelism in the two traces of atmospherics and wind which clearly shows that the atmospherics are a local consequence of instability. These examples are not isolated cases but are extremely frequent.

I must, however, remark that these proofs of the local origin of atmospherics are not necessarily disproofs of the distant action of certain cold fronts such as those of which Mr. Watson Watt has obtained evidence by radiotelegraphic direction finding. To reconcile these two apparent contradictory results it is sufficient to assume that the atmospherics of cold fronts and squalls are to a very great extent quite local and that their effect diminishes very notably within a few hundred metres, but that there may be some, for any given point, which have quite another nature and are of great range. Locally, their small number will prevent their standing out in any special way from the mass of the others. At great distances they will appear only if, at the place of observation, there are no local atmospherics and no atmospherics of other origin.

Mr. GEORGE BOAG (Observer No. 39) (communicated): Atmospherics are noted to be less frequent and less audible at my hill station 100 miles inland and at 2,000 feet above sea level than they are at my coast station at Aguilas, Murcia.

Dr. LESLIE B. C. TROTTER (Observer No. 24) (communicated): The thing that strikes me as most remarkable is that observers that have "tuned in" to transmitting stations of widely differing wave-lengths should be affected equally. This would seem to suggest that an "atmospheric" is analogous to a noise (as distinguished from a musical note), *i.e.*, a jumble of a number of different sound waves of various lengths. Would it be of any use for your purpose to attempt to analyze these atmospheric "noises" by means of an automatic recording apparatus "tuned" to a number of different wave-lengths? One would think it would be possible for an electrician to devise an apparatus that would answer this purpose, thus eliminating personal and instrumental (*i.e.*, different observational station) errors. However careful observers are, one cannot be certain that a disturbance on a given night is the same for A tuned on Daventry as for B tuned on London; time is too short for A to switch over from Daventry to London in order to compare the two. It seems to me that nothing less than an actual graph capable of measurement will settle the question as to mathematical equality of disturbance on different wave-lengths.

Long before I had heard of these tests I had noticed how very much more disturbance we got in the way of atmospherics on frosty nights than on damp, "muggy" or wet ones. Would these atmospherics be strictly local?

THE COMMITTEE (in reply, communicated): We thank Admiral of the Fleet Sir Henry Jackson and the other speakers for their kindly criticism. We hope that it may be found possible, when full details of Captain Bureau's apparatus become available, to carry further the mutual adoption of our fellow workers' methods which Colonel Lee rightly regards as necessary for the reconciliation of differences of result arising from the selective sampling which each method involves. We are glad, too, that Colonel Lee expresses the pleasure which we in this country feel in enjoying the collaboration of our continental colleagues. We note that Colonel Lee's interpretation of the click as a phenomenon of relatively

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near origin reinforces the argument that our estimates of range, based as they are, in many instances, on click reception, are lower limits only. Colonel Lee's argument as to azimuthal distribution in relation to range is a pertinent and important contribution to the range problem.

The numerical phenomenon on which Captain West remarks is, in our view, due to special characteristics of observers and their sets. Observers Nos. 21 and 6 were exceptionally situated in that they were professionally engaged in radio research, No. 21 had previous experience of listening for atmospherics, and special instructions as to procedure, and both had sets of sensitivity considerably above the average for the number of valves in use. Only observers sufficiently experienced and certain of the reliability of their sets could with confidence record the incidence of the minute disturbances which would pass unrecorded by the average observer. In the case of No. 21 the set was deliberately detuned from London to decrease the "signal to static" ratio. Except in the case of specially experienced observers we think Captain West's remarks on the threshold of disturbance explain many of the features of the tables.

In addition to Mr. Brunt's reply to Captain Slee, we would repeat that although our samples were brief and not numerous, they were distributed over half a year and over a wide range of meteorological environment. We share the conviction, expressed by several speakers, that we are far from a complete solution of the problem posed, but we feel we have not in any way strained the evidence, and have not failed to specify the limitations of sampling and method. Are we misinterpreting Captain Slee when we take his remarks as adding a further complication to "short range" dogma, in that the French school regards oversea ranges of atmospheric reception as longer than overland ranges, while Captain Slee seems to suggest that the normal oversea range is the smaller? In any case, the unescapable conclusion from the data very fully set down in this report is that no single one of the very diverse and diversely situated receivers had on any single one of very diverse occasions an atmospheric distribution of which less than 50 per cent. was received at distant stations. This we interpret as definite proof for the conditions of observation; equally definite figures must be produced for other circumstances before definite proof for these circumstances can emerge.

We are in complete accord with Mr. Eckersley's suggestion that in the applications of atmospheric observations to meteorology a valuable control of "sounding range" will be attained by appropriate choice of wave-length. On the comparison between our observations and those of others it is to be noted that our observations were made in conditions which did not favour long ranges, the wave-length being that of short signalling range and the whole path being frequently in daylight. Captain Bureau's results were mainly obtained on longer waves, for which a longer range might have been expected.

Sir Napier Shaw puts a question which is not at present answerable. We can only share the aspiration that means may be found for the prosecution of wider schemes than that which we had the privilege of organizing. The answer to his question on terminology is in the affirmative.

On the question of random coincidence raised by the Secretary of the Radio Research Board we reproduce a typical sheet of data which is perhaps the most convincing evidence of the essential identity of the

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phenomena recorded simultaneously at many stations. It shows the sudden appearance at nearly all stations of an isolated disturbance in a period of almost absolute quiet. The matter covered by this sheet occupied about forty-five seconds in delivery, and it will be clear that there is here no question of a steady stream of independent disturbances at each station, of which a few coincide in time as between stations, but that there is, as has been said, a sharply marked breach of the peace at all or many stations simultaneously. As other evidence on this point the Committee had prepared, but had abandoned as insufficiently rigorous, a group of tables mentioned on p. 331 showing the number of cases in which simultaneous disturbance was experienced at n or more stations, n running up to twenty or more in some cases. The reproduction of one of these tables will show that the falling off in the number of simultaneous observations as n increases is much slower than would be the case were any high percentage of random coincidences present.

JULY 16TH.—FIFTEEN OBSERVERS.

x = no. of cases in which same atmospheric was recorded at n or more stations.

n	1	2	3	4	5	6	7	8	9	10	11	12
x	157	89	53	32	17	15	8	7	4	3	3	3

We appreciate the more Mr. J. F. Herd's remarks on account of his own extensive experience of the complexities of atmospherics research, including much of the directional work on which some parts of the present report depend. We understand that arrangements are now well advanced for a first trial of location of individual sources of atmospherics by two cathode-ray direction finders at the ends of a five-hundred-mile base. It is to be hoped that such methods may be included in an international programme of atmospheric observations.

Dr. Simpson enunciates the fundamental object of the widest form of inquiry on atmospherics rather than that the more limited inquiry to which we first addressed ourselves. The Committee has drafted proposals for such a study as that referred to by Dr. Simpson and Dr. Chree.

In reply to Dr. Chree's question as to relations between atmospherics on one hand and aurora and magnetic disturbance on the other, the only evidence obtained by the Committee is that atmospherics were exceptionally slight on the occasion of greatest magnetic disturbance. We are informed that considerable data as to the relation between atmospherics and magnetic disturbance are in the possession of the Radio Research Station, and it is hoped that the data may be published at an early date.

Referring to Captain Bureau's most interesting contribution, we are not inclined to accept his explanation—that of modulation at the transmitter—of the phenomenon of change in audibility of atmospherics in the presence of a signal. It is well known, and readily explicable in terms of the spectrum concept, that that spectrum component of an atmospheric stream which coincides with the free period of the receiving circuits may give audible heterodyne effects with an incident signal, such that both signal and atmospheric may be raised from inaudibility into audibility by the interaction of one on the other.

On the main question of mean range of propagation it would appear from Captain Bureau's present communication that he on the one hand and we on the other approach the question from different standpoints, he from the transmitting, we from the receiving end. The state of

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present views may be thus summed up. Captain Bureau thinks that a great majority of the atmospherics radiated from a particular front are of short range, but that a few may be of long range. We set out to inquire whether, of all the atmospherics received at a particular place, a great majority are of long range, and we find the answer to be in the affirmative. These two avenues of approach meet only when a front passes over the receiving station, a type of event which occupies but a small portion of the station's history, so that generalizations from the atmospheric disturbance of this selected moment as to the disturbance of the average moment must be made with extreme reserve.

We look forward with keen interest to the publication of full details, including sensitivity data, of the apparatus from which were obtained the striking diagrams illustrating Captain Bureau's remarks. The consideration of these results in the light of such sensitivity data and of the meteorological environment may appropriately be reserved for our next report which will, as has been stated, deal with the meteorology of the days on which our experiments were conducted.

Mr. Boag's independent evidence of a variation in atmospheric disturbance as between two heights above sea level is of great interest, as it supports evidence adduced by Lugeon[1] and unpublished evidence communicated to the Radio Research Station by Mr. S. McClatchie of Stuttgart. The matter demands quantitative investigation, and it is to be hoped that such investigation may soon be undertaken.

Dr. Trotter will be interested to hear that experiments along the lines which he suggests have been in progress at Radio Research Station for some time, the variations in atmospheric disturbance on several selected wave-lengths being recorded simultaneously.

Meteorological Papers Published by the Royal Society.

The following papers have been issued during the present year to those Fellows of the Society who are participating in the arrangement for the receipt of copies of the meteorological papers published in the *Proceedings* of the Royal Society :—

(37) An investigation into the nature and occurrence of the auroral green line, λ 5577 Å. J. C. McLennan, J. H. McLeod, and W. C. McQuarrie.

(38) Some physical properties of icebergs and a method for their destruction. H. T. Barnes.

(39) The electric fields of South African thunderstorms. B. F. J. Schonland and J. Craib.

(40) The mechanism of a thunderstorm. G. C. Simpson.

(41) Measurements of the amount of ozone in the earth's atmosphere. Part 2. G. M. B. Dobson, D. N. Harrison, and J. Lawrence.

(42) Some problems of terrestrial magnetism. S. Chapman. (*Journal London Mathematical Society*, April, 1927).

(43) Currents carried by point-discharges beneath thunderstorms and showers. T. W. Wormell.

(44) On certain average characteristics of world wide magnetic disturbances. S. Chapman.

(45) Recurrence phenomena in terrestrial magnetism. C. Chree and J. M. Stagg. (*Philosophical Transaction Royal Society*, A. 648).

(46) Measurement of the biologically active ultra-violet rays of sunlight. Leonard Hill.

Any Fellow wishing to take part in this scheme is asked to communicate with the Assistant Secretary at 49, Cromwell Road, for particulars.

[1] *Paris, C.-R. Acad. Sci.*, **180**, 1925, p. 594.

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CYCLONES AND THE GENERAL CIRCULATION.

By HAROLD JEFFREYS, D.Sc., F.R.S.

[Manuscript received January 21—Read May 18, 1927.]

I am in agreement with most of Mr. Whipple's note on pp. 332-3 of the QUARTERLY JOURNAL for 1926 concerning my paper of last January. A few passages, however, seem to call for further development.

1.0. Mr. Whipple remarks in passing that I do not prove the stability of the steady circulation I found for the solution of the problem of a frictionless atmosphere with the temperature a function of the latitude alone. It is not difficult to give a discussion adequate to the present purpose. The problem discussed was one where the tidal analogy developed in the earlier part of my paper would be complete, and the stability would be the same as for an ocean of uniform depth covering a rotating planet and disturbed by a small tidal potential symmetrical about the axis of rotation. The possible modes of oscillation about the resulting forced motion can therefore be found by the methods of Lamb's "Hydrodynamics," Chapter VIII. All have finite periods except a certain family of free symmetrical steady motions. These do not imply any departure from stability in the ordinary sense of the term in relation to gyroscopic systems; it is the normal occurrence in such systems for possible motions to exist with the rotational momenta different from those in the actual motion. They cannot, however, be varied, when the system has been actually set in motion, without the application of force from outside; they cannot become large from insignificant beginnings spontaneously, as in true instability. The motion I found is stable in the same sense as any other steady motion of a system with rotation.

2.0. I think Mr. Whipple's objection to my argument leading to the conclusion that the circulation near the poles, if there is any, must be cyclonic, is valid, and that it goes some way to remove a difficulty I had felt. The principal result of my discussion of the effects of friction was that skin friction would be enough to destroy any systematic circulation about either pole in an interval of the order of weeks, unless new angular momentum were brought in by horizontal interchange of air. Further, in many cases this result can be extended to circulations not about a pole. The equations of motion of air in the neighbourhood of a point in colatitude θ are the same as those for motion near the pole, except that $\omega \cos\theta$ has to be written instead of ω, provided certain unimportant terms are neglected. Thus it would apparently be legitimate to consider the equation of angular momentum about any axis in the earth, not necessarily the polar axis, by a process analogous to that on pp. 97-100 of my paper, and to infer that every circulation whose duration exceeds a few weeks has its angular momentum about its centre maintained by horizontal interchange of air. If then we accept the view that horizontal interchange can only bring

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in angular momentum in the same sense as $\omega \cos\theta$, the component of the earth's rate of rotation about the vertical at the centre of the region, it seems to follow that all circulations of long duration must be cyclonic. This is contradicted by the existence of the winter anticyclone of Central Asia. Further, the intensity of the monsoonal variation of pressure seemed to be in reasonable quantitative agreement with the frictionless theory of the earlier part of my paper; and this theory also seems to be in at least qualitative agreement with the rather scattered observations tending to show permanent anticyclonic circulations over Greenland and Antarctica. It seemed curious that making the hypotheses agree better with actual conditions by allowing for friction should at the same time spoil the agreement of several of the consequences with the facts.

2.1. Mr. Whipple opens a way out of the difficulty when he questions my statement that irregularities in the circulation of the atmosphere would lead mainly to SW and NE winds. I inferred this because in a symmetrical circulation modified by surface friction the quantity I denoted by uv (the product of the eastward and southward components of velocity) would have notable values only in the lower layers, where the winds would be in the SW and NE quadrants, and I assumed that the main effect of the irregularities would be to exaggerate these values. I was predisposed to this assumption by the following considerations. The effect of surface friction in the absence of cyclonic agitation would be to produce a drift of air across the isobars towards the low pressure side, and this would continue until all differences of pressure at sea-level were annulled. It seemed a plausible hypothesis that the effect of agitation so complete that the air in every latitude was being continually interchanged with air in other latitudes would be to make the mean angular momentum per unit mass the same in every latitude, so that the higher the latitude the nearer the air would be to the polar axis and the faster it would revolve.[1] If the total angular momentum were as at present there would be easterly winds in low latitudes and westerly ones in high latitudes; but the differences in velocity would be far more violent than in the actual atmosphere. The natural supposition is that, with surface friction and cyclonic agitation both present, the motion of the atmosphere would be intermediate between those inferred from the extreme cases of friction without agitation and complete agitation without surface friction; and then there would be easterly winds near the equator and westerly ones near the poles, but they would be less vigorous than those inferred for the case of complete agitation. On these grounds I was for some time disposed to think that my previous argument, though itself incorrect, must have led to a qualitatively correct result. But it seems that the superficially plausible argument just given is also fallacious. For suppose that the temperature was originally independent of latitude, the isothermal surfaces being horizontal. Then the whole atmosphere could rotate with the earth like a rigid body, and there would be no winds at all. In the absence of friction this state is stable, but

[1] Such " adiabatic " distribution of angular velocity is considered by Poincaré, *Lecons sur les Hypothèses Cosmogoniques*, pp. 31-35, and bears a resemblance to Ferrel's theory of the general circulation.

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is complicated by the existence of free steady motions. But when friction is present, any departure from steady rotation, including the free steady motions, will ultimately die down. Hence the existence of any permanent agitation is essentially dependent on the existence of differences of temperature over horizontal surfaces, and on the winds produced by them. The inference that agitation alone would maintain a general circulation might be correct if the agitation were produced by a Colossus from outside, with a big stirrer, but the agitation that concerns us must arise spontaneously within the atmosphere itself; and since its existence depends entirely on the winds produced by differences of temperature our presumption must be that its character will be intimately related with that of the winds, and that its main effects will be merely to modify the winds.

3.0. From this point of view we can make some progress towards an explanation of the existence of a general circulation, which was adopted as an observational fact in my previous paper. The actual temperature increases towards the equator. A consequence of this is that the westerly component of the wind must increase with height, as W. H. Dines has pointed out.[2] If we imagine the atmosphere started off with an arbitrary distribution of pressure at sea-level, the considerations we have already had show that air would tend to drift so as to efface the differences of pressure, and with them the surface winds. But this would imply westerly winds at all levels above the ground. This arrangement could not constitute a permanent motion. For the upper layers would drag the lower ones forward by eddy-viscosity, and since there would be no surface wind and therefore no skin friction, the lower air would be accelerated towards the east. If, on the other hand, the lower air acquired a finite velocity, there would be skin friction, but then this friction would produce a westerly force on the whole column of air above the place where it acted, and again some, and perhaps all, of the air would have an acceleration in longitude. The distribution of pressure being symmetrical by hypothesis, there is nothing to balance these frictional accelerations, and the motion cannot be permanent unless some interchange of air takes place and produces a quasi-viscous drag. The drag of the upper air on the lower was not considered in my paper, but is mentioned by Mr. Whipple, and seems to provide a reason against the possibility I was previously unable to exclude, that a differentially heated atmosphere might settle down into a steady state with no surface winds anywhere.

3.1. A few suggestions can now be made about the nature of the circulation to be expected. If the temperature contained a term $\sin^2\theta$, a similar term would be present in the pressure at a given height, a term in $\sin\theta\cos\theta$ in $\partial p/\partial\theta$, and therefore one in $\sin\theta$ in the geostrophic wind at a given height. If the pressure at sea-level were uniform, the west wind would increase most rapidly with height at the equator, and if we start off with no surface winds the velocity at a given height other than zero will be greatest at the equator. We have seen that it is from such differences of velocity that the horizontal interchange must arise, and its effect

[2] *Nature*, Vol. 99, 1917, p. 24.

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will presumably be to reduce these differences. Hence we shall expect the upper air to be accelerated in high latitudes and retarded near the equator. But since the vertical variation of velocity above about 1 km. is fixed only by the distribution of temperature, this implies that easterly surface winds will develop in low latitudes and westerly ones in high latitudes.

3.2. There seems to be no need for the westerly circulations to extend to the poles. To maintain such circulations NE and SW winds would have to extend in spirals all the way to the poles, a state of affairs probably difficult to realize dynamically. It seems more plausible that the SW wind should turn round before it reaches the pole. If it does so, the shift would most frequently occur through the air passing around the north of a cyclone, its direction changing from SW through SE to NE, and the velocity would diminish through friction in the process. Since the transmission of angular momentum depends on the product uv, and the average value of u is zero, we shall expect the SE winds to make the larger contribution to the angular momentum near the north pole. Thus weak anticyclonic circulations may perhaps be expected near the poles; this is contrary to what was inferred in the previous paper.

3.3. It seems possible at first sight that the requisite interchange of air could be achieved by superposed currents at different levels, without the distribution departing from symmetry. Clearly if cyclones can produce the amount of interchange needed, the same amount could be produced by having the currents from the north and south one above the other, instead of side by side and each extending to ground level, so long as the quantities of air moving in each direction remained the same. There is, however, a serious objection to such a scheme. If the distribution of winds remained symmetrical and horizontal eddies were absent, there would be no reasonable alternative to a symmetrical distribution of pressure and temperature. But there is every reason to believe that the facts that the actual surface wind usually deviates from the isobars by only 10°-30°, and that the wind at heights above a kilometre is practically geostrophic, express a general hydrodynamical relation and would persist in any type of circulation on a rotating planet. We saw previously that in conditions of symmetry these rules would only give about 1/20 of the transfer of momentum required to maintain the circulation. The interchange must therefore consist mainly of irregularities extending down to the ground, and involving notable asymmetry in the distribution of pressure.

3.4. An explanation may now be sought for the small intensity of anticyclones in comparison with cyclones. The explanation usually given is that if an anticyclone rotated too rapidly it would have to have a region of low pressure at its centre, but the fact that the pressure is not low seems to be accepted as a result of observation rather than inferred on dynamical grounds. A hydrodynamical explanation may be found in a consideration of the circulation[3] around a line of particles surrounding the centre of the anticyclone.

[3] The circulation is defined as $\int V \cos\lambda \, ds$ taken around the contour, where V is the resultant velocity in space, ds an element of length, and λ the inclination of the velocity to the tangent to the contour.

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The calculation of the circulation involves the use of a fixed frame of reference, not one rotating with the earth. The circulation around a closed contour moving with the fluid can vary only through viscosity and, possibly, differences of temperature. The former would tend to reduce it through time, but not to reverse its sign; the latter might act in either direction, and its total effect may be small during the development of a single whirl. It seems reasonable, then, that the circulation around such a contour does not change sign during the development of a single vortex. But the circulation around a contour during average conditions is in the same sense as the component of the rotation of the earth about a vertical in the neighbourhood, and we may infer that the circulation in an anticyclone is also in this sense. The extra rotation relative to the earth's surface, which is what we observe and is negative in an anticyclone, must then be less than the undisturbed rotation if it is not to reverse the sense of the circulation. If the contour turned upside down, the circulation retaining the same sense around the contour, the sense relative to the earth would be reversed. A circulation in the sense unusual in either hemisphere could also occur if the contour crossed the equator during the development of the disturbance. Either event must be exceptional. A cyclone is under no restriction of this kind, and can in some cases acquire a rotation several times faster than that of the earth.

4.0. To sum up, it appears that if there were no variation of temperature with latitude the atmosphere could rotate with the earth like a rigid body, and this would be a stable state. But increase of temperature towards the equator implies that the velocity from the west must increase with height, and in these conditions it appears that frictional interaction between different layers of the air and between the lowest layer and the ground would suffice to destroy any motion symmetrical about the earth's axis. Irregular horizontal interchange of air must therefore be developed, and it seems that this implies a system of cyclones resembling in their main features those we know. One effect of the interchange would be that the normal winds at the surface must be on the whole as much easterly as westerly, and reasons are suggested to explain why the easterly prevailing winds are near the equator and the westerly ones in higher latitudes. It seems probable that this mechanism would give slow anticyclonic circulations near the poles, apart from possible local conditions tending to reverse or intensify such circulations.

DISCUSSION.

Mr. F. J. W. WHIPPLE said that he was glad that Dr. Jeffreys had been able to modify his view regarding the general circulation of the atmosphere. Attention might be called to two curious features of the subject. Amongst meteorological phenomena the trade winds stood out as having a nice simple explanation which could be reproduced in every text-book of geography. That explanation had proved quite inadequate, but the theory which had been substituted for it was much more difficult and hardly satisfying even to its authors.

In the latitudes where westerly winds prevail the general flow is in the same direction at all heights: in the latitudes where there are easterly

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winds at the surface the flow is reversed aloft. It might have been expected that in the former region the flow would be steady and that in the latter region there would be greater disturbance. Actually the westerly flow was continually interrupted by cyclones, whilst the easterly flow in the trade wind belt was proverbially steady. This was a paradox which might well be examined from the mathematical point of view.

Mr. L. C. W. BONACINA asked Dr. Jeffreys whether his results applied only to the surface, and whether they left room for the circumpolar westerly winds at high levels blowing practically as far as the poles.

With regard to Mr. Whipple's difficulty about the westerly temperate zone cyclones and the tropical trade wind cyclones, surely the answer was that the westerly wind cyclones of temperate latitudes formed essentially at the interface between the south-westerly winds and the outflowing polar winds—in other words, along the polar front, whilst the tropical cyclones formed at the interface between the opposing trades at the season when one trade system crossed the equator.

Dr. JEFFREYS, in reply to Mr. Whipple, said that a full explanation of the phenomena was likely to be extremely difficult. The problem of the generation of eddies in a viscous fluid flowing in a tube or between parallel plates had hitherto resisted all attempts at solution, and it was unlikely to be made easier by the fact that in the atmosphere rotation would have to be taken into account as an additional controlling factor.

In reply to Mr. Bonacina, on any theory the tendency of westerly winds to increase with height would cause a steady anticyclonic circulation in polar regions to be confined to heights under a few kilometres.

Discussions at the Meteorological Office.

The meetings for the discussion of recent contributions to meteorological literature during the session 1927-28 have been resumed at the Meteorological Office. The meetings are held on alternate Mondays at 5 p.m., beginning on Monday, October 10, 1927. The subjects for discussion are as follows, the names of the openers being shown in parentheses :—

October 10 (Dr. G. C. SIMPSON, F.R.S.)—
Recent research on lightning in America.

October 24 (Dr. C. CHREE, F.R.S.)—
La Cour, D.—Sur l'erreur moyenne des moyennes mensuelles des éléments magnétiques observées à l'observatoire de Rude Skov. *Copenhagen, Dansk. Meteor. Inst., Publ.* No. 1, 1927.

November 7 (Mr. W. H. BIGG)—
Ficker, H. *v.*—Richtung von Wind und Wolken auf Teneriffa. *Wien, SitzBer. Ak. Wiss.*, **135** (11a), 1926, pp. 307-322; also in *Wien, Festschr. Zent. Anst. Meteor. Geodyn.*, 1926, pp. 15-30.

November 21 (Dr. J. GLASSPOOLE)—
Hellmann, G.— Untersuchungen über die jährliche Periode der Niederschläge in Europa. *Berlin, SitzBer. Ak. Wiss.*, 1924, No. 11, pp. 122-152.

December 5 (Mr. W. C. KAYE)—
Petitjean, L.—Application à l'Afrique du Nord de la méthode Norvégienne de prévision du temps. Alger, 1927. 8vo. Pp. 19, pls. 3.

The dates for subsequent meetings are as follows :—
1928. January 16 and 30; February 13 and 27; March 12.

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EARLY WATER-MILLS IN RELATION TO CHANGES IN THE RAINFALL OF EAST KENT.

By GEORGE M. MEYER, B.A., Assoc. M. Inst. C.E.

[Received in original form February 21, revised March 28—Read May 18, 1927.]

PART I. WATER-MILLS.

In order to appreciate the evidence quoted in the present paper some knowledge of the history of flour-mills—a subject which does not usually come within the purview of meteorology—is essential. Reference may be made to *The History of Corn Milling*, by Richard Bennett and John Elton (Simpkin, Marshall), the first two volumes of which contain the facts of present interest.

Windmills were only introduced after the first crusade when they began to displace the earlier water-mills. Of the latter the first documentary evidence is contained in a charter by which King Ethelbert granted to the monastery of SS. Peter and Paul half the usage of a mill in the royal Kentish town of Wye. In the South of England the Roman type of water-mill was used, much as described by Vitruvius about 20 B.C., although that writer showed the mill geared down instead of geared up, as now employed. Water-mills, however, do not seem to have been adopted to any extent by the Romans before 398 A.D. and it is doubtful whether they were introduced into this country before the Anglo-Saxon invasion.

The possession of a water-mill and of water rights was a local monopoly of considerable value. In consequence, records of ownership and legal disputes regarding them have come down to us from the middle ages.

CANTERBURY WATER-MILLS.

At the time of Halsted's great Survey of Kent, at the end of the eighteenth century, there were five mills in Canterbury, the same number as when Somner wrote 150 years earlier. These mills were:—King's (or Eastbridge), Abbott's, Westgate, Shafford's (or Dean's or Scepeshotes) and Barton. Somner (ed. of 1640, p. 42) gave also a list of seven other mills which were in use in A.D. 1150. These seven were:—Shanford (or Sameleteford), Gudwold's, Monk's (or Munechemeln), Hotte's, Crine's, Saliford (or Shulford) and St. Mildred's.

The disuse of these seven mills between the middle of the twelfth and the middle of the seventeenth century may have been due either to the competition of windmills, or to a decrease in flow of the river Stour. Some additional light, however, is thrown upon the question by a controversy which is recorded by Somner (*loc. cit.*). It appears that, as early as the reign of Henry II., the monks of Christ Church complained of the lack of water for their mills and put the blame upon rival mills. The King therefore ordered that they should have restored to them as much water

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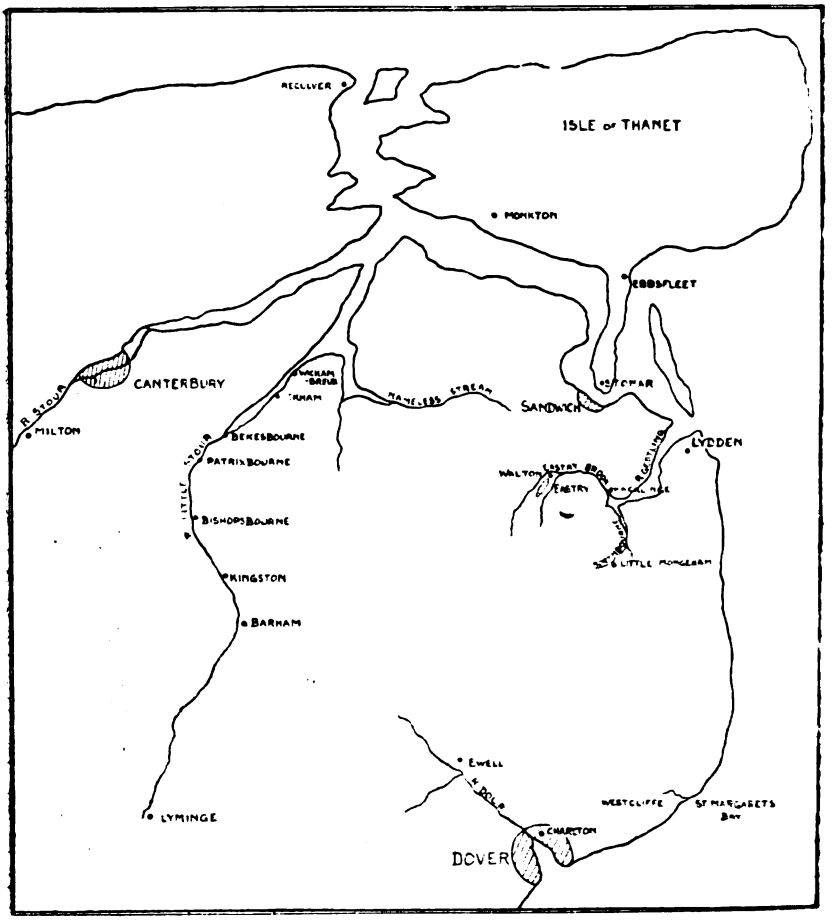
as they used to have in the time of Henry I. Little more than a hundred years later, Archbishop Peckham (1279-1292) was charged by the citizens of Canterbury with diverting the river by means of trenches to feed his mill at Westgate. The matter was the subject of a legal inquiry, and the jury found that this diversion had been done partly by Archbishop Kilwarby (1272-1278) and partly by Archbishop Boniface (1244-1270).[1]

Thus it seems that there must have been a decrease in the flow of the Stour, beginning in the reign of Henry II. and becoming acute suddenly in the times of Archbishop Kilwarby and Archbishop Peckham.

This sudden reduction of flow about 1275 agrees very fairly with the curve of rainfall for Eurasia (Brooks, C. E. P., *Climate*



EAST KENT IN DOOMSDAY

[1] Somner, ed. 1640, p. 38; Hasted (*History of Kent*, 2nd ed., Vol. XI., pp. 31 and 139) quotes Battely's edition of Somner, p. 21.

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through the Ages, p. 403) which is derived from various sources not including the present evidence.

In Magna Carta there is a clause which provided that all weirs were to be done away with. This points, possibly, to a decreased flow in many rivers as early as 1215; but, on the other hand, care must be exercised not to attribute to decreased rainfall, ordinances designed merely to prevent poaching upon water rights down stream. These weirs may, however, have been merely fish-weirs.

The remaining evidence presented in this paper calls for somewhat intimate topographical knowledge. The accompanying sketch map (Fig. 1) indicates roughly the coastal outline in 1087 and the position of places mentioned. Further information can most readily be obtained by consulting the large maps issued in connection with the East Kent Regional Planning Scheme Survey by Prof. P. Abercrombie and Mr. J. Archibald (Univ. Press of Liverpool). These maps show the 12ft. 6in. contour which is not given on the Ordnance Survey.

Reference should also be made to *The Water Supply of Kent* by William Whitaker (memoir of the Geological Survey, 1908) and to *Ancient Britain* by Dr. T. Rice Holmes (Clarendon Press, pp. 660, 679-82, 685). In order to trace changes in the minor streams in S.E. Kent a search was made for records of water-mills in Doomsday Book. For this purpose were collected all the extracts given by Hasted in Volumes IX., X. and XI. of the second edition of his *History of Kent*.

The Little Stour.

Of mills on the course of the Little Stour the following are recorded:—Two at Wickham Breux, four at Ickham, one at Bekesbourne, four at Patrixbourne, two at Bishopsbourne and one at Barham.

Dr. Rice Holmes (*Ancient Britain*, p. 679) found that Bryan Faussett, writing between 1767 and 1773 (*Inventorium Sepulchrale*, ed. C. Roach Smith, 1856, p. 35), had recorded that the stream about a mile below Kingston was seldom or never dry. Bishopsbourne is about a mile below Kingston and Barham is about a mile above it. Again Philippott (*Villare Cantianum*, 1776, p. 62) stated, that in the reign of Edward the Third "there was a small navigation out of the river of Stour up to this place," referring to Bekesbourne. In fact, Bekesbourne was at one time a non-corporate member of the Cinque Ports, attached, curiously enough, to Hastings as head port (Boys, *Collections for History of Sandwich*, 1792, p. 770). It is clear, therefore, that there have been very great changes in the quantity of water carried down along this valley.

Inspection of the map accompanying the Regional Survey will show that the 12ft. 6in. contour ends abruptly about a quarter of a mile down stream from Bekesbourne, while the fifty foot contour also crosses the valley below the village.

The stream must therefore have been tidal up to within a quarter of a mile of Bekesbourne, when this place was attached to the Cinque Ports, while the silting up of the channel was probably caused by the decrease in the flow occurring between the date of

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Doomsday (when there was a mill as far up as Barham) and the latter part of the eighteenth century when Faussett usually found water at Bishopsbourne.

Anyone crossing the stream to-day as low down as Littlebourne will have difficulty in believing that it could ever have carried even a small navigation at Bekesbourne, a mile further up stream. On May 1, 1902, Dr. Holmes walked along the valley from Barham to Bekesbourne. He records that "there was not so much as a teaspoonful of water in the channel, and a policeman whom I met near Kingston told me that it had been dry for the last five years."

The Dour.

A consideration of Doomsday records of water-mills on the Dour involves several difficulties. References to half a mill probably indicate that the water rights were held only on one side of the stream. Thus we find recorded five and one half mills at Ewell, one at Charlton and one at Dover itself. Of the latter we hear, "In the entrance of the port of Dover, there is one mill, which damages almost every ship, by the great swell of the sea, and does great damage to the King and his tenants, and it was not there in the time of King Edward. Concerning this, the grandson of Herbert says that the Bishop of Baieux granted it to his Uncle Herbert, the son of Ivo."

It has been stated by many writers that this mill was a tidal mill; but no evidence for the statement has been discovered. It appears rather more probable that the Dour was tapped near its mouth and the mill-race was carried on a jetty as far seaward as possible in order to make use of the greatest possible drop at low tides.

Two mills are recorded as being situated at West Cliff, near St. Margaret's, north of Dover. An authority on the district considers that these also must really have been placed on the course of the Dour. There is a large spring at the base of the cliffs at St. Margaret's, but otherwise there are few indications, at present, that there could have been a stream on the high ground at West Cliff within historical times. Every other case investigated by the present writer points to mills of the period being water-mills, otherwise suspicions would have been raised that these two might have been windmills.

It is thus at least clear that the whole character of the Dour, in the eleventh century, must have been quite different from its present inconstant form.

In the Doomsday Book are recorded also two mills at Milton, above Canterbury, on the Stour, one at Monkton, presumably deriving its supply from the same river, or from a small tributary which has since disappeared, and one mill is noted as being at Reculver on the northern branch of the Stour.

The Northbourne and Eastry Brook.

There are two small streams to which particular attention remains to be given, the Northbourne and Eastry Brook. These

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unite and at the present time flow into the Stour near Stonar. Their early history is very peculiar in many ways.

On the Northbourne Doomsday records one mill at Little Mongeham, *where there is now no water*, and as to Eastry we find it stated:—

"In the lath of Estrei, in Estrei hundred, the archbishop himself holds Estrei. It was taxed at seven sulings. The arable land is . . . In demesne there are three carucates and seventy two villiens, with twenty two borderers, having twenty four carucates, there is one mill and a half of thirty shillings, and three salt-pits of four shillings, and eighteen acres of meadow. Wood for the pannage of ten hogs."

Doubt has been expressed as to whether the salt-pits were actually situated in Eastry village. Most certainly salt-pits were at times placed upon estuaries as at Milton, Tunstall, Faversham and Ospringe (Kemble, *Saxons in England*, Vol. II., p. 70), but this extract from Doomsday cannot be quoted with confidence in order to prove that the tide flowed up to Eastry village at the end of the eleventh century. On the other hand, the mention of water-mills proves that there must have been a stream of considerable volume and very different to the present insignificant brook which rises at about the level of high tide. In the past eight hundred years the height of the saturation level must, therefore, have been greatly depressed.

Indications near the present steam-mill at the cross roads close to Worth, suggest that the earlier windmill on this site in its turn had replaced a water-mill. It is suggested as probable that a mill-race tapped the parent stream near Walton, and that the saucer-shaped depression in a field adjoining the present mill represents the pool above the old mill. If these suppositions are correct the saturation level must have fallen some ten or twelve feet.

Mills at Sandwich, Stonar and Ebbsfleet are mentioned in the thirteenth century (Boys, W., *Collections for History of Sandwich*, pp. 659, 661). The corporation of Sandwich owned two mills, the history of which can be traced fairly completely until the middle of the sixteenth century (Boys, *loc. cit.*, pp. 671, 672, 684, 688). Possibly these mills were worked by tidal power, although this is by no means certain, as will appear from the consideration of one other mediæval mill which now will receive somewhat full investigation.

This mill was situated at Lydden close to the sea, and adjacent to the old haven of Sandwich, which has long since been silted up and become dry land. In order to appreciate the matter it is essential to know certain facts of local history.

On May 16, 1285, the Patent Rolls record a grant by Edward I. to the Barons of Sandwich "for digging of a certain trench over the lands lying between Gestlynge and Stoneflete, and from Stoneflete to Sandwich, to the intent that the passage of the water called North Brook which was at Gestlynge, should be diverted so that it might run to Sandwich for the perpetual commodity of the town and its barons thereof" (Dugdale, *History of Imbanking*, 1662, p. 36, also Boys, *loc. cit.*, p. 790). This work is still in existence. It is a most remarkable system of artificial canals by

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means of which the Eastry Brook and the Northbourne are tapped near their sources, carried along the sides of the valleys with a minimum fall, across the marsh and over the parent stream by means of a very low aqueduct,[2] and thence, by a cunningly designed channel, led into the town of Sandwich.

Whatever may have been the condition of the Northbourne and Eastry brook in the reign of the Conqueror, the marshes through which they run must have become by 1285 very similar to what we find them to-day. The demand for a water supply by Sandwich, perhaps, only indicates the prosperity of the port and not a failure of local wells. No writer appears to have appreciated the astounding skill of the engineers who carried out the work. The commissioners were two justiciars, Solomon de Rochester and Roger de Norwode.

The success of this clever piece of engineering seems to have roused the Prior of Christchurch to emulation, with disastrous results which ended in a lawsuit (Dugdale, *loc. cit.*, p. 41, and Boys, *loc. cit.*, p. 664) in 1313. The jury then found that "the said Prior and Convent had anciently a certain mill in a place called Lydene which mill being burnt in time of war there was no other built till the Prior then living about [ten][3] years past erected a new one, and they said that after the building thereof, the said Prior raised a certain gutter, four feet high, which had been made in former times, for conveyance of the water from the upper parts of the country . . . and that the course of the said water, which passed through the before mentioned gutter, passed to that place wherein those condemned persons had been wont to be drowned (*sic*) and their bodies carried out to sea . . . and that after the same gutter was so raised, the water descending from the upper parts mentioned could not pass through it, whereby not only. . . but the drowned bodies could not be conveyed to the sea by that stream as formerly; and all this by reason that the water had not its passage there as usually; and *that the ground without the gutter so increased and grew higher that the stream could not have its course there.*"

It seems very clear, at any rate, that the Northbourne and Eastry brook were bringing down into the Gestling considerable quantities of silt which were being discharged into the sea. The unfortunate Prior, who had been charged with flooding 1,500 acres, seems to have tried to use the stream to drive a mill, probably in the same way as had been done before the war during which the original structure was burnt. Meanwhile the flow had decreased and, although silt had been still carried out to sea before the Prior's efforts at engineering, yet, after the bed had been raised four feet in order to give a fall to work the mill, the speed of the stream decreased so much that it promptly silted up the "gutter" and flooded the neighbourhood. The war in question was probably the landing of the French at Sandwich in 1217.

[2] This is not marked on the 6in. ordnance map, although aqueducts probably not much larger or of greater antiquity are shown on sheet LIX, S.E. of Wiltshire. The ordnance maps use the names North Stream and South Stream for the modern representatives of the tributaries of the ancient Gestling.

[3] Blank filled by reference to the charge.

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If the above interpretation be correct, assuming[4] that the flow of the Gestling indicates the rainfall of the country, we may deduce that:—

The rainfall about 1303 was much less than in 1217. It is much less to-day when no silt is carried down. On the other hand it must be remembered that the streams, meanwhile, had been tapped to supply Sandwich with water. This alone would reduce the force of the current. Consequently the latter part of the deduction must carry far more weight than the former.

Part II. Rainfall.

It remains to consider whether these variations in the rates of discharge of Kentish streams correspond to simultaneous variations in the rainfall. Just as a business concern makes out an annual balance sheet, or an engineer makes out the heat-balance of an engine, so is it possible—at least theoretically—to make out an annual water balance sheet for any given district. This balance may be expressed in the form of an equation, the various terms of which represent convenient items in the analysis of the gains and losses of water suffered by the district.

Thus we may write:—

$$R = E + S + s + U_1 + U_2 + G$$

where the symbols used represent the following quantities of water expressed in tons:—

R = rain falling on the whole district.
E = evaporation from the whole district.
S = discharge of rivers and streams at the boundaries of the district.
s = discharge of springs between high and low water marks.
U_1 = discharge of underground circulation at neighbouring land boundaries.
U_2 = discharge of underground circulation at boundaries below high water mark.
G = water going into or coming out of storage by change in the saturation level.

Of these symbols, S, s, U_1, U_2 and G may be either negative or positive.

At once it is obvious that in order to decide definitely whether a variation in S corresponds to a variation in R, it is necessary to know either that none of the other quantities has changed or to what extent it has changed.

The Evaporation from the Surface of the District.

Furley's two volumes on the *Weald of Kent* give very full particulars of the changes in the afforested area within historical times. Probably evaporation from a forest is less than that from pasture or arable.

Changes from arable to pasture are likely to have affected E and probably occurred after the Black Death and during the Napoleonic Wars.

[4] Vide Part II.

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These surface factors, no doubt, also influenced the proportion of rainfall which escaped under all the other categories, because a relatively impermeable surface would increase S and decrease the remaining terms.

Discharge of Rivers and Streams.

The discharge of a stream at its mouth is not generally equal to the sum of its tributaries. Besides loss by evaporation there must be considered percolation through the bed of the stream into the strata below.

In this particular district of Kent this factor may have very great importance and may have been variable during the period. It will be convenient to consider, particularly the two minor streams, the Northbourne and Eastry brook, since their total length is small and the district is best known to the author.

The typical valley section at the present day appears to be a U-shaped chalk depression having the sides of the U filled with "brick-earth." Crossing such a valley the soil is shallow both on the heights and at the bottom, while it is deep on the slopes.

It has been suggested above that the Gestling was bringing down silt as late as 1303. At present it seems to be guiltless of any erosion. The Stour, even at the present day, carries little or no silt, and is not eroding its banks for a distance of at least 15 miles above the commencement of the estuary (Robertson, J. K., *Richborough Transportation Depot, Proc. Inst. C.E.*, Dec., 1921, CCX., p. 166). The exact date at which Sandwich Haven began to silt up cannot be stated. Rapid deposition seems to have begun soon after the middle of the fifteenth century. Boys (p. 733) gives a report of the time of Edward VI. attributing it to embanking by Cardinal Moreton at Sarre, while Leland (VII., p. 127, Oxford ed., 1770) blamed a shipwreck in the Haven in the time of Pope Paulus (1464-1471).

It appears very probable, then, that the silting up of Sandwich and possibly of other South-coast ports was due to the decreased flow of the streams running into them and that all theories of the action of the "Eastward Drift" deal with quite secondary effects.

Now if, indeed, these streams brought down vast quantities of silt before they decayed into comparative insignificance, it follows that they were eroding their channels quite rapidly before the fifteenth century. Rapid erosion would have brought their waters into closer contact with the underlying chalk as the force of their streams cleared away the overlying clays and brick-earths. Chalk is very porous and liable to fissures and, consequently, it is highly probable that the streams were bled by the underground circulation to an increasing extent as they worked down to the chalk. This would tend to increase U_1, U_2 and G at the expense of S.

A secondary effect would be to increase the flow of the springs at the base of the chalk cliffs, as at St. Margarets.[5] Close investigation of the mills at West Cliff therefore seems desirable, since there seems some possibility in this case that a former surface stream is now represented by a spring at the foot of the cliffs.

[5] H. E. Stigoe in discussion on Forster Brown's Paper, Proc. Inst. C.E., CCXV., p. 78.

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Underground Water.

The classical paper on this subject is *Underground Waters in the Kent Coalfield*, by E. O. Forster Brown, Proc. Inst. C.E., June, 1923, Vol. CCXV., pp. 27-114). A full account of the matter is clearly out of place, but briefly the conclusions of immediate importance are to be found on pp. 58-59 of his paper, where particulars of faults so far discovered in the course of mining operations are given.

The existence of faults and fissures would only affect the use of S as a measure of R, if such passages have either increased or decreased their discharge of water from the surface to the lower strata during the period considered. They may have been silted up, or they may have opened through the agency of earthquakes and earth movements.

A full discussion of this matter would be long and tedious. Attention is, however, called to the following list of earthquakes which probably affected the district from the eleventh to the fourteenth century.

1382, May 21, intensity 8 local. Davison, Dr. C., *History of British Earthquakes*. Gervase of Canterbury (ed. Stubbs, 1880, p. 324) gives April 21st.

1299, Hasted (2nd ed., Vol. XI., p. 128) quotes Matthew of Westminster (Dr. Davison, Jan. 5th, 1298).

1274, Capgrave, John, *Chronicles of England*, ed. 1858, p. 103. (Henry de Knyghton gives date 1275 under which date Dr. Davison records one also in Somerset.)

1246, June 1, Davison *loc. cit.*

1129, *Anglo-Saxon Chronicle MS.* "*E*" Earthquake probably applies to this district.

1089, *Anglo-Saxon Chronicle MS.* "*E*" Earthquake "over all England."

The records of these earthquakes raise serious doubts as to whether the opening of fissures may not have played an important part in reducing the discharge of surface streams. The water which percolates into the chalk must, however, find an exit somewhere. It may escape either by springs on the margin of the sea, as at St. Margaret's, by underground channels leading into neighbouring land districts or possibly by underground channels opening on to the sea bottom.

In the case of the Northbourne and of Eastry brook, however, these complications appear to be simplified. Reasons will be given for believing that the combined stream (the Gestling) carries off much of the percolation as well as the surface flow of these streams.

In the case of several of the streams in the enclosed marsh, there are to be found springs which rise up visibly from the bottom. The depth of the chalk beneath the surface of this marsh is unknown, except at one spot, near the banks, but it is probably at least 60ft. at the lowest point. It seems likely, therefore, that the springs in the marsh discharge most of the underground flow from the districts drained by the Northbourne and Eastry brook, so that the "Gestling" (or its modern equivalents), flowing through the gap in the higher ground near Hacklinge, carries almost all the drainage from the district.

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Unfortunately, there is one possibility of error. Similar springs occur in the bed of the stream which rises near Staple and flows by Wingham into the Little Stour. Now this stream is remarkable in only one way. It has no name, and further, Holinshed records that it had no name in the seventeenth century. This raises the suspicion that perhaps it is a new stream due to a change in the underground circulation carrying into its bed, water which formerly flowed into Eastry brook. The suggestion, however, seems very improbable. Apart from this very dubious instance there seems no possibility of river-capture, in the ordinary sense, having occurred anywhere in the district during the period considered.

On the whole, therefore, the volume of the Gestling may be regarded as very probably a fair measure of the rainfall. But the records of the Gestling are in harmony with those of the Great and Little Stour and the Dour. Therefore, it is probable that the variations of flow in these latter streams also indicate variations of rainfall of similar order.

It is fitting to close this inquiry by pointing out certain important practical matters which may be affected by its further consideration in the future.

As early as the reign of Queen Anne proposals were made to establish a harbour near Sandown Castle (Boys, pp. 707, 717, 762). The matter dragged on until the reign of George II., but nothing was done (*Regional Survey*, p. 67. *Pritchard's History of Deal*, p. 176). If this part of Kent develops industrially the question of the ports will become of the greatest moment, and the decisions may well be influenced by the past unfortunate history of neighbouring harbours. It is, therefore, clear that investigation of the local streams and of their capacity for carrying silt, both now and in the past, assumes an immediate practical importance not always obvious in purely scientific studies. Dredging has brought increasing prosperity to the port of Blyth in Northumberland, which has the advantage (as have the Dutch ports) of a flat situation. If the steam-dredger had been at work in the thirteenth century Blyth might have been to-day a city teeming with commerce. Possibly the Sandown harbour project may be revived.

The author desires to express his thanks to the following gentlemen, who have most kindly assisted him in obtaining information as to the history of the district: J. Archibald, Dr. F. E. Bromley, F. A. Cloke, Dr. F. W Hardman, LL.D., F.S.A., and G. C. Solley.

DISCUSSION.

Dr. J. GLASSPOOLE asked if Mr. Meyer could give some idea of the flow of a stream capable of driving one of these old watermills, so that a measure of the change in the rainfall could be made. He suggested as a first approximation that in the earlier days the run-off was determined by the rainfall less the evaporation, while in recent times additional factors such as percolation had affected the flow of the streams. It is possible to determine the average rainfall for the recent 35 years for any given catchment area, and so to calculate what the flow would be if these two factors alone operated. A comparison of these flows for the two periods would give an estimate of the change in the rainfall if

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the evaporation was considered constant, which is a legitimate assumption for a first approximation. He thought that if Mr. Meyer would continue the investigation and set out a quantitative estimate of the change in the rainfall, the paper would have an additional value.

Dr. Glasspoole also pointed out that the present rainfall of the east of Kent was comparable with that of the Thames Valley, so that given a sufficiently large catchment area the absence of a considerable stream could not be attributed to lack of rainfall.

Dr. S. W. WOOLDRIDGE said that he knew the district treated in the paper intimately, and had for some years been studying its streams from a geological point of view. It seemed worthy of note that the peculiar form of the Downs between the Stour Gap and the coast led to a definitely augmented rainfall, as might be seen from the maps in the Society's recently published *Rainfall Atlas*. The operation of this orographic factor favoured the Stour basin as compared with its western analogues, the Medway, Mole, etc. Again, it was noteworthy that the Stour, lacking a main consequent trunk stream on the Weald clay, was more dependent on sub-surface chalk water for the maintenance of its flow than the other Wealden streams. It did not respond so rapidly to short period rainfall fluctuations as, *e.g.*, the Medway might do very markedly, owing to the prompt and effective run-off from the clay lands of its middle course. The underground supplies by which the Stour was largely fed made it, in a measure, independent of all but very considerable rainfall variations. (It is worth noting an analogous case, that of the Wandle, which, draining an area of about fifty square miles of chalk, succeeded during a period of eighteen months (1858-9) in maintaining a daily flow whose minimum was 10,000,000 gallons, although the rainfall of the period was inconsiderable.) In the light of these facts the evidences of a markedly diminished flow in the Stour were all the more striking, and the speaker thought that Mr. Meyer had proved his case. A close scrutiny of the flood-plain features of the Wealden streams certainly suggested a notably fluctuating volume in the recent past and a deep cut in the alluvium of these streams, observed over a wide area, might plausibly be correlated with the well-known thirteenth century rainfall maximum. Direct evidence of a phase of silting-up in the valleys attributable to an earlier rainfall minimum might quite well be forthcoming. It did not seem at all likely that fissuring of the chalk associated with slight earthquake shocks would sensibly affect the level of the water table. Provided that the streams were flowing (*i.e.*, that the water table was above the valley bottoms) fissures would simply fill with water up to the water level. If they extended above the water level they would merely afford increased facilities for the downward percolation of surface water and the water table might conceivably be raised thereby. Slight fissuring of the chalk might well lead indeed to an increased outflow of the springs rather than the reverse. Only if the fissures traversed the water zone from top to bottom could they lead to leakage.

It was suggested that the area north of Hertford, where watermills have been in use for a long period, might afford the basis for a similar study.

Dr. CHREE remarked that if a mill were only in occasional use it could be worked from a very small stream, if a mill pond or dam were used for storage; he did not know whether such dams were impossibilities in Kent.

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Mr. L. C. W. BONACINA remarked on the great complexity of hydrogeology of the chalk, a fact to which Mr. Meyer was evidently very much alive. If any Fellow were particularly interested in the behaviour of "nail-bournes" in relation to rainfall, he (Mr. Bonacina) recommended him to make periodical visits to the remarkable system of "swallow-hole" fissures near Potters Bar. In that district at the village of North Mimms was a stream, running off the London clay, which in ordinary weather could be seen disappearing through a complicated system of "swallows" in the chalk beneath drift deposits. The underground stream drained into the river Lee. In wet weather, however, in time of flood, the site of the "swallows" was covered by a lake which overflowed in quite the opposite direction into the river Colne. The amount of water in the channel responded very rapidly to the fluctuation of rainfall, and he could believe that any prolonged vicissitudes in the rainfall might work considerable changes in the hydrology of the system.

Mr. G. M. MEYER in reply said: Dr. Glasspoole asks for particulars of the flow required to drive a watermill. Half a million gallons a day would supply one horse-power for twelve hours a day, assuming that a 10ft. drop and storage for half-a-day's flow were available and that the machinery had the high overall efficiency of 50 per cent.

The rare short periods during which the Alkham Valley tributary of the river Dour rises as high up as Drellingore are signalised by a flow of about this amount, as measured just above Alkham. As far back as 1538 this spring was said to flow only once in six or seven years (Whitaker, W., *loc. cit.* pp. 55-56). Other springs occur at Alkham and there was a mill below that place at any rate 120 years ago (Hasted, *loc. cit.* Vol. VIII.). The normal flow of the river Dour itself amounts to roughly four million gallons a day (Stilgoe, H. E., *Proc. Inst. C.E.*, 1908, Vol. CLXXII.).

If percolation materially increased between the eleventh and fifteenth centuries, then the evidence from Doomsday and other early sources does not, of course, necessarily point to a mediæval maximum of rainfall. The history of the Gestling, however, seems to negative this geological explanation, since, apparently, that stream receives most of the underground drainage as well as the surface flow from its catchment area.

Dr. Wooldridge accepts a change in rainfall as the cause of the alterations in flow of these chalk streams. His opinion as a geologist, possessing intimate knowledge of the district, is of particular interest and value.

Special attention was given in the paper to the possible effects of fissuring following upon slight earthquakes, because Mr. Forster Brown had laid stress upon the influence of faults and fissures in determining the nature of the deeper drainage. Dr. Wooldridge considers that the level of the water table is unlikely to have been affected by such causes. His view is certainly supported by the evidence of the Gestling. Change in the rainfall appears to be the only possible cause for the undoubted decreased volume of all these streams and of the lowering of the water table.

East Kent is largely chalk country, so that the surface is peculiarly permeable. Any extensive water storage presents grave difficulties in places where the water table is far below the surface. No doubt Dr. C. Chree was unaware of the extremely transient and infrequent character of some of these streams—at least since the latter part of the fifteenth

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century—especially in the upper parts of their valley. Clearly, no practical person would provide the capital cost of a mill capable of running only for a month or two, once in every five or six years. The fact that it was worth while installing mills high up these valleys indicates clearly that in 1087 the streams must have run for some months at least every year.

There was omitted from the paper a reference to one watermill at Lyminge recorded in Doomsday (Hasted, *loc. cit.* Vol. VIII., p. 83). According to Hasted, the valley of the Little Stour is generally dry between Ottinge (a mile lower down) and Barham.

As a student of the history of Kent the author trusts that the geologists and meteorologists between them will be able to arrive at some unanimous conclusion as to the cause of the decay of these streams. If this decay indeed brought about the loss of Sandwich Haven, the matter is deserving of the most careful attention from a purely utilitarian motive.

Note on a Thunderstorm of June 17, 1927.

On 17th June, 1927, a thunderstorm passed directly over Falkirk at 2.10 p.m. S.T. from SW to NE. The storm was in no way remarkable for its severity, but seemed more like a winter than a summer thunderstorm in that is passed so quickly. I don't think there were more than 4 or 5 peals of thunder and flashes, one being directly overhead, and the others more or less distant. The overhead flash struck the Falkirk steeple in the centre of the town, 150 feet high, I fancy on the south side at the top, and demolished about 30 feet of the masonry, which seems to have mainly fallen to the north, with the result that the damage appeared mainly to be on the north side. One stone, 10¾lbs. in weight, which I have in my possession, was driven through the roof of a house belonging to me in Bank Street, 120 yards nearly due north from the site of the steeple. Judging from the point the stone struck the slated roof and the point at which it must have struck the plaster of the ceiling below, the stone must have been travelling at an angle of at least 35° with the ground level without allowing for the momentum lost by the contact with the slates. The base of the steeple is about 10 feet above the level of Bank Street and the height of the building in Bank Street at the point where the stone went through the roof is about 30 feet above the level of the street, so that, assuming the stone came off the top of the steeple, in the course of its carry of 120 yards it fell about 130 feet.

My knowledge of meteorology is confined to observation of rainfall, etc., and my knowledge of physics and dynamics is nil, but the facts above stated should, I think, provide an interesting problem to any one with the requisite scientific knowledge.

A. Nimmo.

Westbank, Falkirk.
June 28, 1927.

Major A. H. R. Goldie, through whom the account of the storm was received, writes:—

I estimate, from the figures given by Mr. Nimmo, that the stone which penetrated the roof of the house in Bank Street must have been projected from the steeple with an initial velocity of 500 feet per second, that is, with something approaching the muzzle velocity of some howitzers.

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A Waterspout off the Needles.

The following account of a waterspout seen off the Needles, I.O.W., has been received from Mr. C. E. Clowser, 16, Havelock Road, Southampton.

The morning of August 24th was sunny and quiet at first, but isolated cumulus clouds soon appeared and showed an unusual degree of upward extension relative to the area of their bases. A particularly large cloud formed over the western end of the Isle of Wight and the wind was S.W., force 3. At 9.10 a.m. (S.T.) a tongue of cloud began to grow downwards from the base of the big cloud and towards the N.E. Within a minute it had almost reached the sea a mile North of the Needles, but never quite did so. At this stage the sea beneath the funnel-shaped cloud became violently agitated. It was as if a shell from a great gun had sent up a splash which had not subsided. The vortical movement in the waterspout was very distinct and the "core" was lighter in colour than the edges, suggesting a hollow centre. The phenomenon ceased at 9.15, when the cloud tongue very rapidly dispersed from the bottom upwards and the sea beneath became quiet.

The most imposing part of the spectacle was the cone of cloud (above the waterspout) which rapidly increased to an enormous size, towering upwards many thousands of feet. Before the waterspout dispersed rain began to fall from the cloud, and after it had quite disappeared torrential rain fell over the adjacent part of the Isle of Wight. During its brief existence the waterspout appeared to travel a short distance towards N.E.

Winter Thunderstorms, 1926-1927.

The preliminary report on the census of thunderstorms between October 1, 1926, and March 31, 1927, contains the following details.[1]

Thunderstorms occurred somewhere in the British Isles on 96 days out of 182. The numbers of days for each country, in the various months, were :—

1926.	England.	Wales.	Scotland.	Ireland.	British Isles.
October ...	16	11	10	9	21
November ...	18	11	10	12	20
December ...	5	1	4	0	8
1927.					
January ...	14	8	16	14	23
February ...	6	1	3	2	7
March ...	14	5	3	7	17
Totals ...	73	37	46	44	96

The inquiry is being continued during the present winter and records of the place, date and time of the occurrence of thunder or lightning, as in previous winters, will be extremely welcome. Notes should be sent to the undersigned at Langley Terrace, Oakes, Huddersfield.

S. Morris Bower.

[1] See *Q.J.R. Meteor. Soc.*, **52**, 1926, p. 426.

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REPORT ON WINTER THUNDERSTORMS IN THE BRITISH ISLANDS, FROM JANUARY 1ST TO MARCH 31ST, 1926.

By S. MORRIS BOWER, F.R.Met.Soc.

[Manuscript received April 25—Read May 18, 1927.]

§1. INTRODUCTION.

The annual record of winter thunderstorms[1] was continued during the first three months of 1926. The enquiry was conducted on the same lines as in 1925; appeals for reports of thunderstorms were sent to about forty-five journals in London and the provinces. Reminders were sent at regular intervals during the period under investigation so that all storms should have fairly equal chances of being reported. Special letters were sent to local newspapers and individuals in several areas where winter thunder appears to be infrequent and where there are few observers. The Director of the Meteorological Office was again good enough to circularize the observers of the British Rainfall Organization, and the British Broadcasting Corporation kindly broadcasted appeals for thunderstorm information from all their stations on four occasions. The author was permitted to examine the meteorological logs from 68 lighthouses at Trinity House and reports were received from the Scottish and Irish Lighthouse Commissioners. Records were included from the weather reports of the Meteorological Office. The observations required were the place, date, and time of the occurrence of thunder or lightning, and the direction in which the latter was seen—especially at night. Further information of the following character was invited:—

1. The time when the storm passed overhead, or was nearest, with its direction; how long it lasted.
2. Severity of storm; much or little thunder or lightning or both.
3. Whether it was accompanied by rain, hail, or snow.
4. Direction and strength of wind; change of wind (if any).
5. Whether there was a change in temperature during the storm.

Reports were received from 1,487 individual observers of whom 1,356 were in England and Wales, 61 in Scotland, 56 in Ireland and 14 on the Continent. The total number of reports was 2,486. The figures for the previous winter were 823 observers and 1,591 reports. The map (Fig. 1) indicates the distribution of observers for 1926 in the British Isles. It will be noticed that there are large areas in which there are very few observers and often these are districts in which winter storms appear to be infrequent. It is very important that evidence, either negative or otherwise, be obtained from these areas, and the help of anyone, resident or having friends resident, in these parts, will be extremely welcome. Copies of the annual letter to observers, containing the map reproduced in Fig. 7, will gladly be sent to any who will help in obtaining records.

[1] *Vide* "Winter Thunderstorms in the British Islands," CAVE, C. J. P., *Q.J.R. Meteor. Soc.*, **49**, 1923, pp. 43-53. "Report on Winter Thunderstorms in the British Islands from January 1st to March 31st, 1925," BOWER, S. M., *idem.*, **52**, 1926, pp. 405-414.

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§2. Summary of Results.

Thunder or lightning occurred somewhere in the British Isles on 49 out of the 90 days in the first three months of 1926. The monthly figures for each country are shown in Table I., to which the final figures for the three previous winters are added for comparison. The investigations during the winters of 1923 and 1924 were made by Mr. Cave. It will be noticed that winter 1926 was much less stormy than its predecessor. In both Tables I. and II., storms in progress at midnight have been recorded only for the day on which they commenced, and a few doubtful records have been omitted.

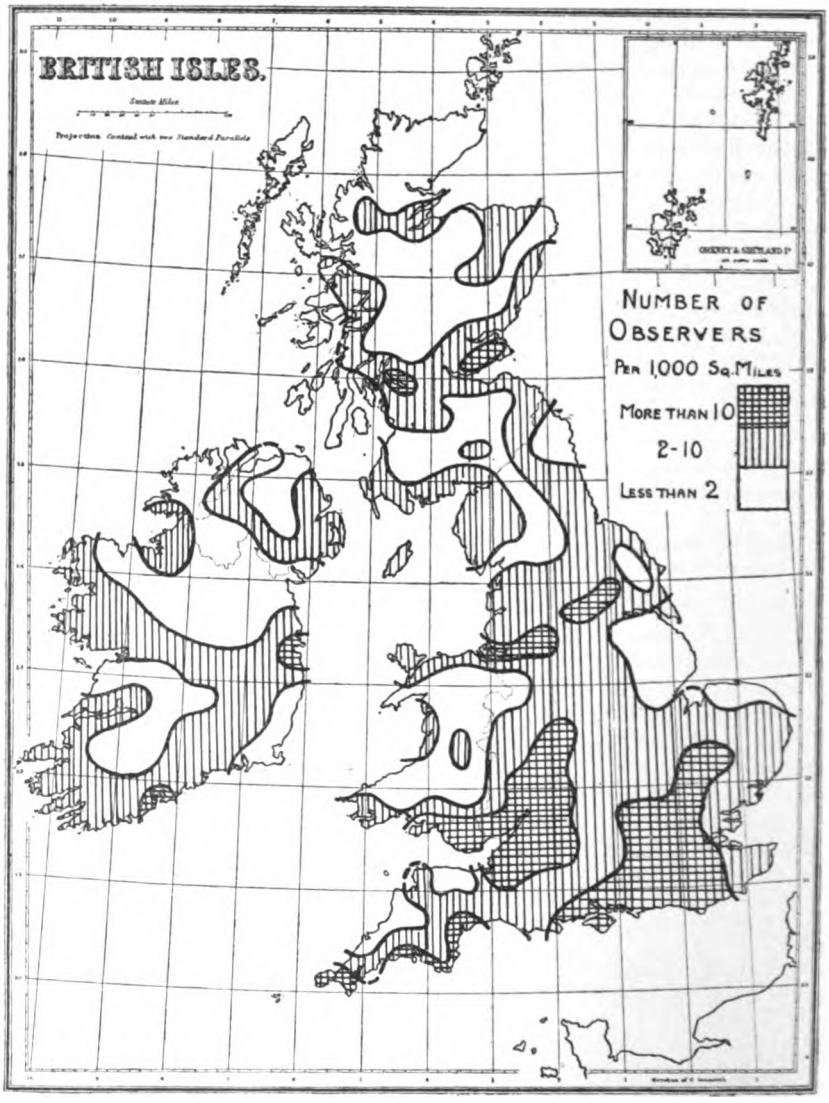

FIG. 1.—Distribution of Thunderstorm Observers in 1926.

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TABLE I.—NUMBER OF DAYS ON WHICH THUNDER OR LIGHTNING OR BOTH THUNDER AND LIGHTNING WERE REPORTED.

1926.		England & Wales.	Scotland.	Ireland.	British Islands.
January . . .		17	4	15	21
February . . .		11	6	5	13
March . . .		9	11	6	15
Totals for three months	1926	37	21	26	49
	1925	46	27	22	57
	1924	35	22	11	48
	1923	43	20	17	52

The number of days for Scotland and Ireland is probably still too low on account of the small number of observers in those countries.

The dates on which thunder or lightning was observed and the number of reports relating to each day are shown in Table II. The figures give some idea of the relative sizes of districts affected by the storms, but in this connection it must be remembered that in England and Wales there are more than twenty times as many observers as in either Scotland or Ireland. Table II. may be compared with the map of depression tracks (Fig. 3) and the maps of individual storms (Figs. 2 and 8).

§3. INDIVIDUAL STORMS.

January.—The first notable thunderstorms in this month were those associated with a moderately deep depression which moved slowly north-eastwards and which was centred very near Iceland on the morning of the 7th. The storm areas on January 6th and 7th are shown in Fig. 2A. A secondary trough to the main depression passed across northern England on the latter date (Fig. 3—Track A).

No thunderstorm of any moment seems to have been associated with the deep depression which covered a large part of the north-eastern Atlantic between the 9th and the 12th.

A few reports regarding very local storms on the 13th and 14th are of especial interest, since the British Isles were then mainly under the influence of an intense and maintained anticyclone centred near Finland. Cold Easterly winds were blowing, temperature was falling generally and local thunder was reported from unusual places, such as Middlesbrough.

Associated with the depression which moved along Track B (Fig. 3) was a slight local storm in south-western Ireland and another in south-western Scotland, both on the 19th. Hail fell at several stations.

On the 25th, thunder was reported from many places in western Ireland and Scotland. A large number of records were received of a storm about 16h. over a small area round the Firth of Forth: this disturbance was followed at 17.40 by a very local storm on

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the west coast of Cumberland, and again after midnight there were slight sharp storms in a number of places in south-west Yorkshire and Cheshire. In the latter case thunder was confined to a curiously short interval of time round 00.25 on the 26th: the storm did not appear to travel very much but was accompanied in most places by strong gusts of wind; the barograph at one station showed a sharp rise in pressure.

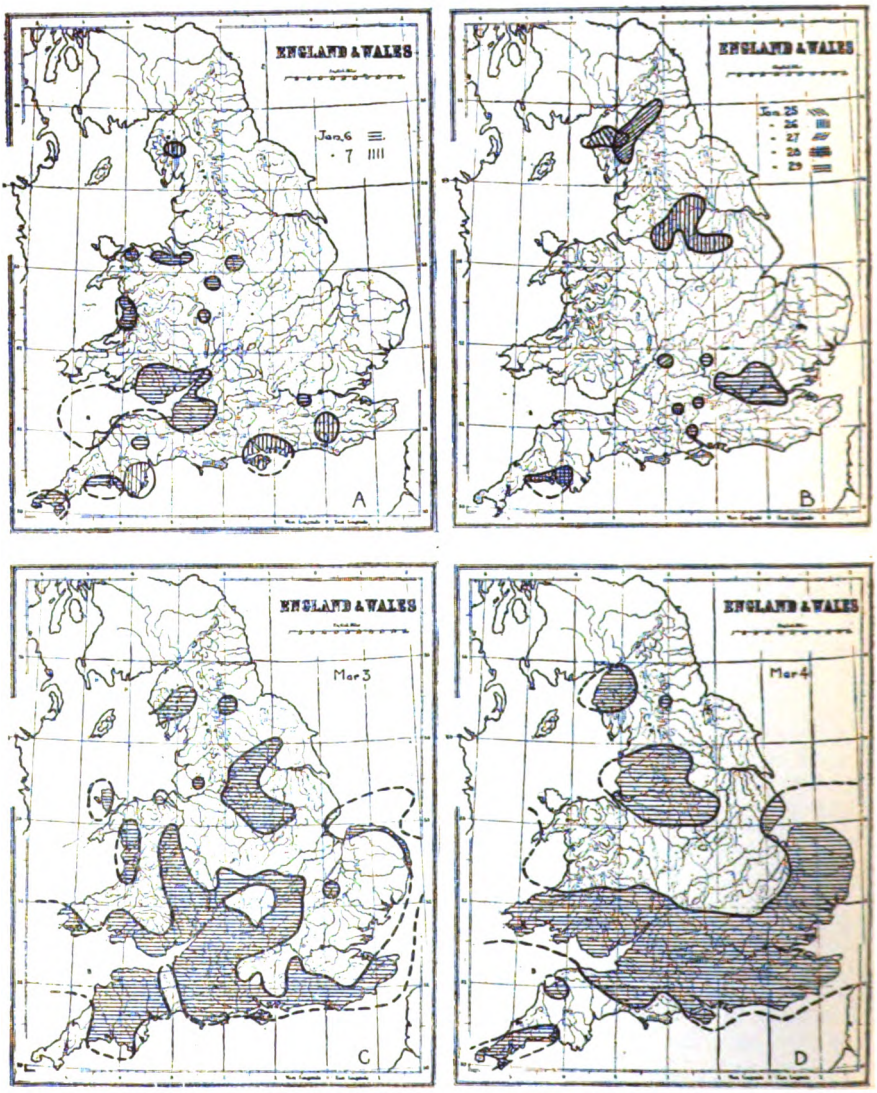

FIG. 2.—Storm Areas on certain dates.
(A) Jan. 6th—7th, 1926. (B) Jan. 25th—29th, 1926.
(C) March 3rd, 1926. (D) March 4th, 1926.

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TABLE II.—DAYS ON WHICH STORMS WERE REPORTED AND NUMBER OF REPORTS RECEIVED.

1926. Date.	January.			February.			March.		
	Eng. & Wales.	Scot.	Ireland.	Eng. & Wales.	Scot.	Ireland.	Eng. & Wales.	Scot.	Ireland.
1	—	—	—	3	—	4	3	—	—
2	—	—	—	—	—	—	4	—	—
3	6	—	1	3	—	—	287	11	12
4	1	—	—	—	—	—	185	6	10
5	1	—	3	3	—	—	11	—	1
6	44	2	17	—	1	—	—	1	—
7	48	—	5	1	—	1	—	—	—
8	—	—	—	—	—	—	—	6	—
9	—	—	—	—	—	—	19	13	2
10	—	—	2	—	—	—	11	1	2
11	2	—	—	—	—	—	—	2	—
12	—	—	1	—	1	—	—	—	—
13	2	—	1	—	—	—	—	—	—
14	4	—	—	3	—	—	—	—	—
15	—	—	—	3	3	23	—	—	—
16	—	—	—	883	1	25	—	—	—
17	3	—	—	39	—	1	—	1	—
18	—	—	2	6	1	—	—	—	—
19	—	2	2	—	—	—	—	—	—
20	—	—	—	—	—	—	—	1	—
21	—	—	—	2	—	—	—	—	—
22	—	—	—	1	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—
24	2	—	2	—	—	—	—	—	—
25	9	25	24	—	1	—	—	—	—
26	32	3	4	—	—	—	4	—	—
27	14	—	2	—	—	—	18	—	—
28	3	—	—	—	—	—	—	4	4
29	60	—	2				—	—	—
30	1	—	—				—	1	—
31	3	—	3				—	—	—
"Nil" Reports	199	14	8	147	16	7	113	7	8
Totals	434	46	79	1094	24	61	655	54	39

On January 29th, when a deep secondary trough moving along Track C (Fig. 3) was centred near the Isle of Man, a short but rather severe storm visited a well-defined area near London (Fig. 2B). The thunder occurred in most places about 15.45 and was accompanied by a sudden squall of heavy rain or hail; an observer at Barnet reported that the wind backed suddenly to SE and then veered rapidly to SW, the temperature falling about 8° : at Harrow the temperature fell 9°. Several stations just outside the area reported a fine afternoon. The storm areas of January 25th to 29th, during which time the primary depression was mainly north-west of these Islands, are shown in Fig. 2B.

The distribution of thunderstorms in England and Wales during January is shown in Fig. 4

February.—A slight storm of short duration was observed at 22.25 on the 1st over the Channel south of Eastbourne : it was not

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accompanied by any squall of wind, only by light rain, and was apparently associated with a very shallow trough centred in the Channel (Track D). On the 7th there was a storm in Norfolk where

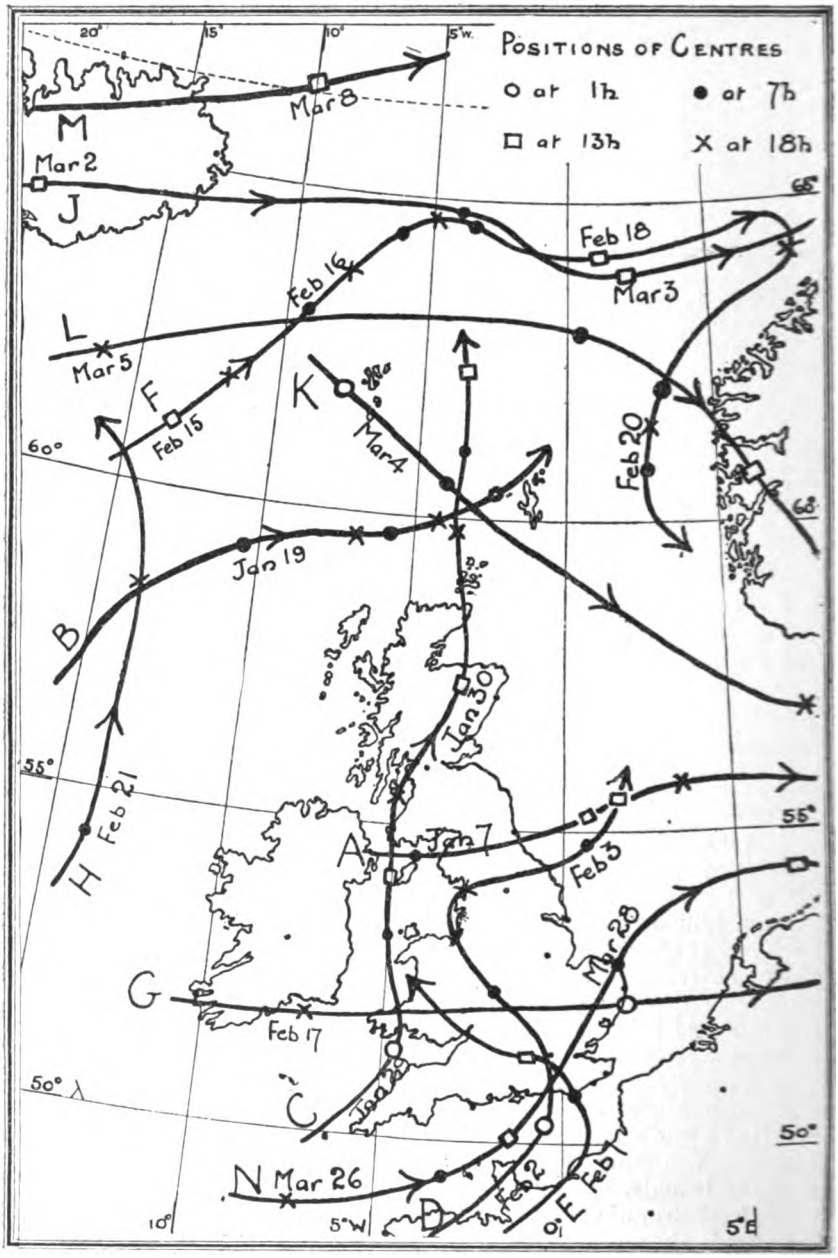

FIG. 3.—Movements of certain depressions, 1928.[2]

[2] From the *Monthly Weather Report* of the Meteorological Office, by kind permission of the *Controller*, H.M. Stationery Office.

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a strong Easterly wind was blowing round a small low pressure area on Track E: the temperature was reported to have remained constant during the storm. The large depression which had been present over the north-eastern Atlantic for a few days previous to the 15th took up a position south of Iceland on the afternoon of this date: the very widespread thunderstorms about the 16th associated with the passage of this depression between Iceland and the Faeroes (Track F) are specially treated in Section 5 of this report. There were no storms of special interest during the closing days of February.

The features of the distribution map for February (Fig. 5) were largely determined by the extensive storms round the 16th,

FIG. 4.—Thunderstorm distribution, January, 1926.

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and although the disturbed area in February was very much greater than in January, the number of days with storms was decidedly less.

March.—A depression centred over Iceland on the 2nd deepened considerably and took up a position north-east of the Faeroes on the 3rd (Track J): it caused widespread thunderstorms on the evening of that date (Fig. 2c). Cold air reached the British Islands from the north-west and a rapid fall in temperature took place. A secondary depression formed near the Faeroes and moved south-eastwards on the 4th (Track K) and again there were widespread thunderstorms in these Islands, several storms following one another across the country (Fig. 2d). The storm areas (Figs. 2c, 2d and 8) associated

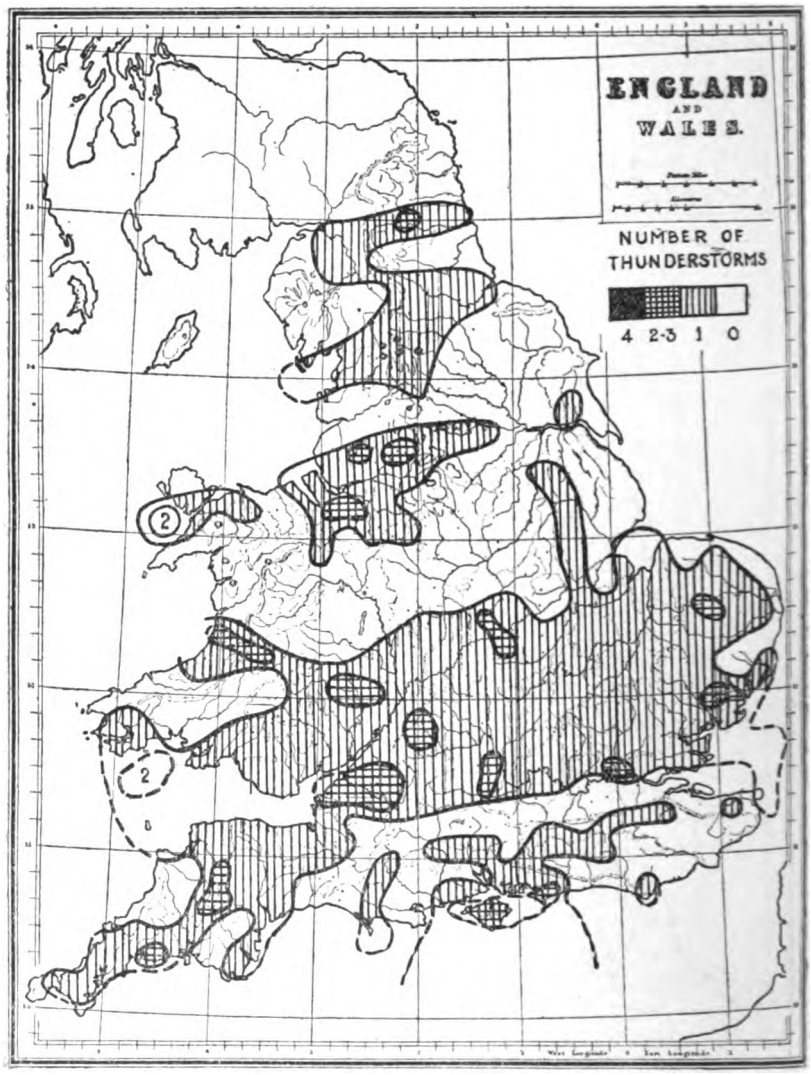

FIG. 5.—Thunderstorm distribution, February, 1926.

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with depressions on Tracks J, K and F (Fig. 3) have several features in common and form an interesting comparision.

The storms of March 9th and 10th were of a very local character, the thunder on the 9th being confined mainly to a short interval round 11.20 (*vide* Track M).

On the 26th, thunder occurred on the Essex coast with light Easterly winds, and on the afternoon of the 27th thunderstorms took place over a very small area mainly in Wiltshire and Berkshire, the storm being particularly severe at Wantage. The storms on these two days occurred in the left front of a depression advancing up the Channel (Track N).

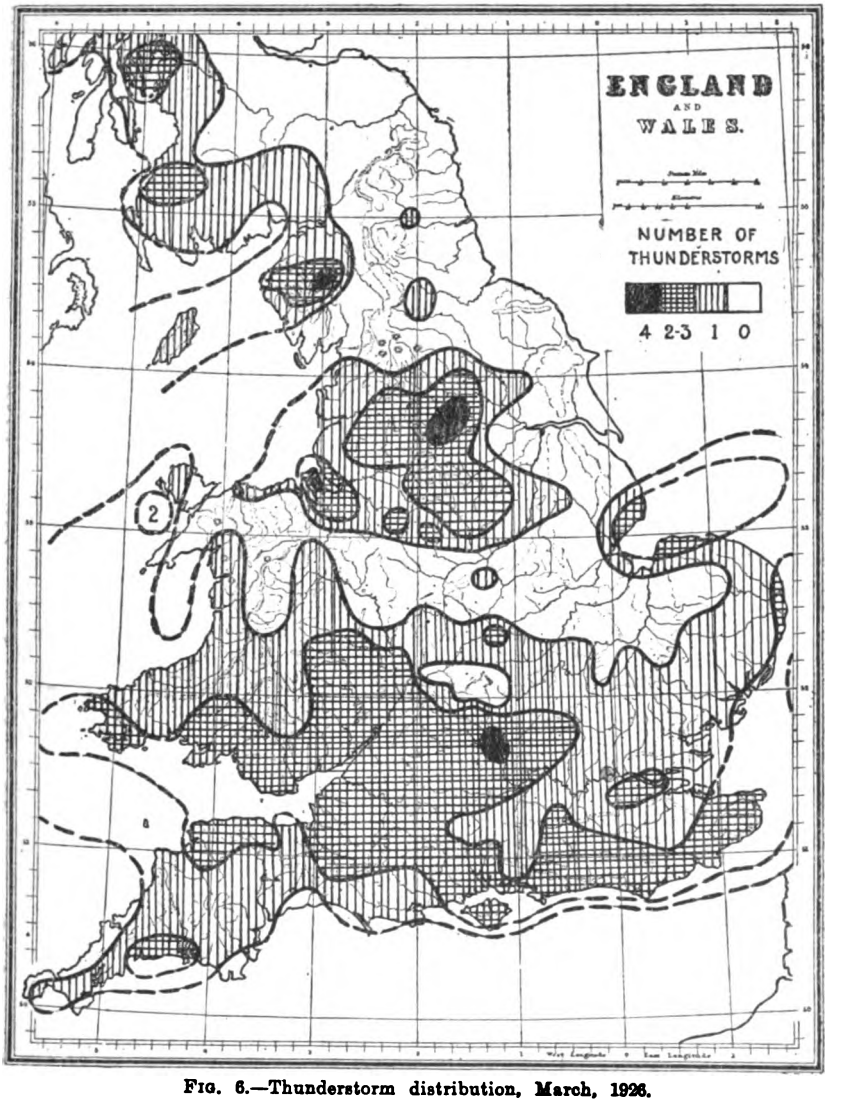

FIG. 6.—Thunderstorm distribution, March, 1926.

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The distribution of storms during March is shown in Fig. 6.

Summary.—The dates of widespread thunderstorms during the three months were February 16th, March 3rd and March 4th. On each of these three days there was a very deep depression centred in the neighbourhood of the Faeroes with almost straight isobars over the British Isles; the barometric situations on these occasions were very similar (*vide* Fig. 9B). Local storms in widely separated areas occurred on January 6th and March 9th. The main storms associated with secondary depressions, large enough to be shown on the weather maps, crossing the British Isles are those on January 7th, January 29th, February 17th and March 27th; on these dates the disturbed areas were relatively small and well defined, the storms being moderately severe. Thunder in anticyclonic weather occurred on January 13th.

§4. Distribution of Storms.

The monthly distribution maps (Figs. 4, 5 and 6) have been constructed from the charts of individual storms with the addition of data extracted from the *Monthly Weather Report* of the Meteorological Office. It has not been possible, on account of the scarcity of records, to include Scotland and Ireland, but an attempt has been made in the map for the whole winter (Fig. 7) to give a general survey of the storm distribution in these countries. It must, however, be especially mentioned that the parts of Fig. 7 relating to Scotland and Ireland have been constructed from only 305 and 216 records respectively and cannot therefore be as assured as the part relating to England and Wales, which has been drawn from about 2,000 records. Reports from light-vessels and ships have made it possible to determine the limits of certain storms which extended partly over the sea.

England and Wales.—A comparison with the records for the previous winter shows that, although 1926 had fewer days with storms, the total area experiencing at least one storm was much greater in 1926 than in 1925. The stormy areas in Cornwall, round the Severn Estuary and Bristol Channel, in south-west Yorkshire and in the Lake District, which were prominent features of the 1925 map, were again marked in 1926; but the storm areas in southern Surrey and southern Sussex have not recurred. The belt of country free from thunder stretching from Dorset to The Wash, which has been a regular feature in most winters, was reduced in 1926 to a small area running approximately east and west through the Midlands. This was mainly due to the very widespread storms on February 16th and March 4th.

Scotland.—No part of Scotland appears to have had more than four storms; this is a contrast to 1925 when thunder was reported on eight or ten days in several districts. The large number of storms recorded in western Ross-shire in 1925 was not maintained in 1926; otherwise the stormy areas, but not the numbers of storms, on the west coast of Scotland were very similar in the two years.

Ireland.—Unlike Scotland and England, there were more storms in Ireland in 1926 than in the previous winter; disturbed areas appeared again in Counties Mayo, Donegal, Kerry and Cork, being especially pronounced in the last three counties mentioned.

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Storms were again most prevalent in Munster, while County Wexford remained an undisturbed area.

Channel Isles.—Only one storm occurred in Jersey and Guernsey against an average of five in the previous winter.

§5. Thunderstorms around February 16th, 1926.

The storm phenomena of this group appear to have been associated with the passage across the British Isles of at least five "squall lines." The five chief lines may be denoted conveniently by the letters A to E (*vide* Fig. 8). The areas in which thunderstorms marked the passage of a squall line, together with the isochronous lines joining places at which thunder occurred at the

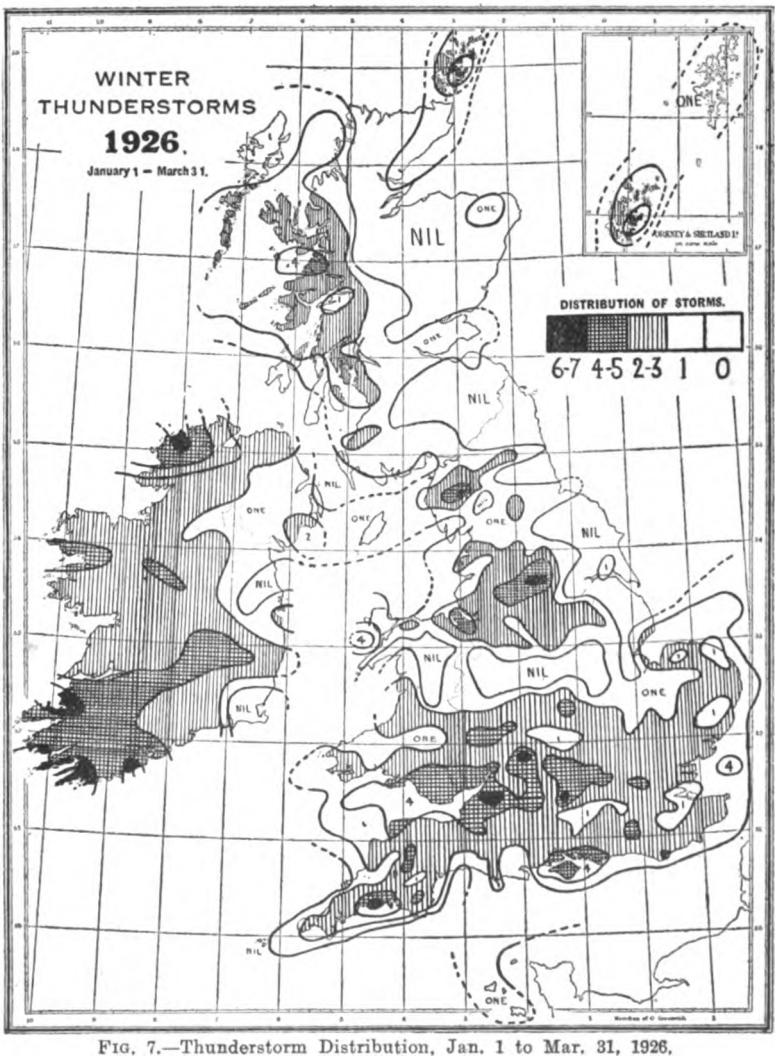

Fig. 7.—Thunderstorm Distribution, Jan. 1 to Mar. 31, 1926.

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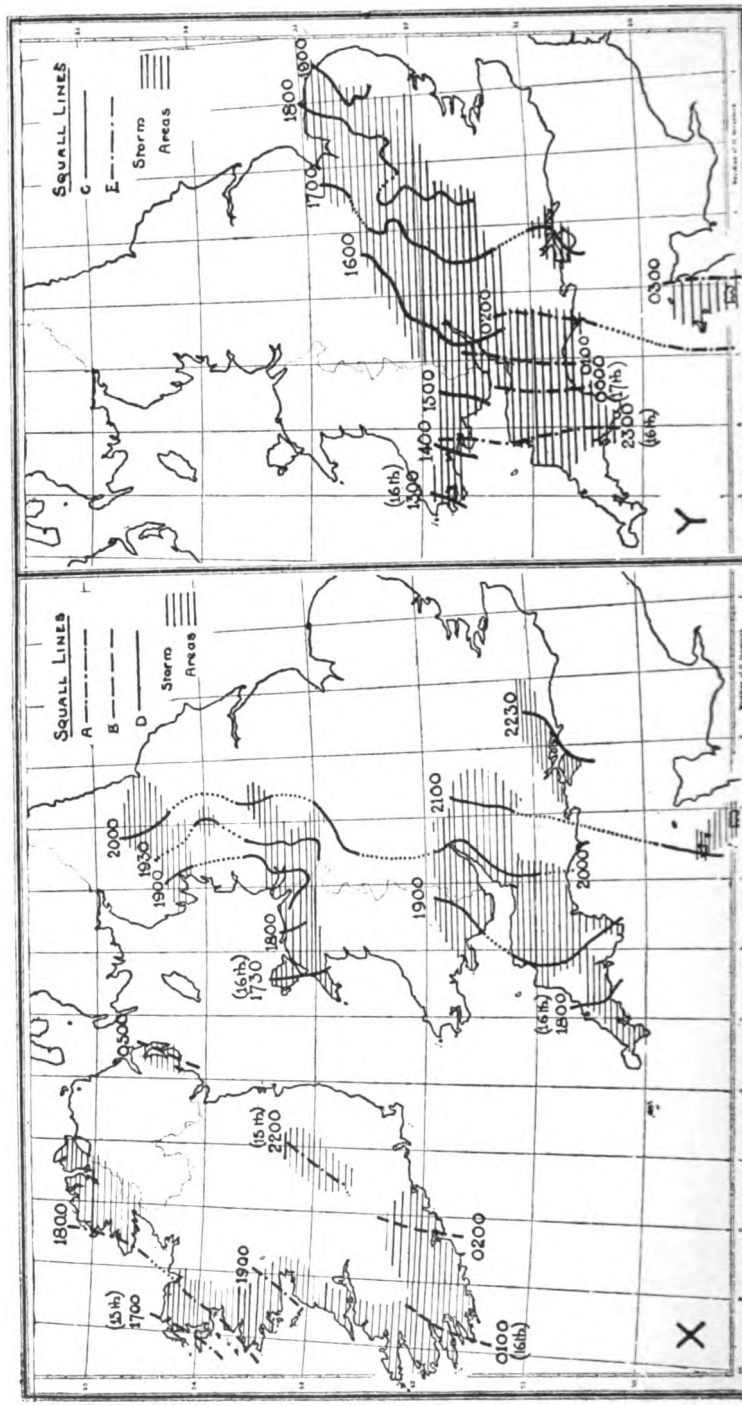

FIG. 8.—Storm Areas and Isochronous Lines of "Feb. 16th, 1926" group. (X) Squall lines A, B and D. (Y) Squall lines C and E.

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same time and associated with the same squall line, are shown in Fig. 8, which is based on records from about 700 observers. Additional records of hailstorms, unaccompanied by thunder, have made it possible to trace the movements of the squall lines outside the thunderstorm areas and to connect the isochronous lines in one area with those in another. During the passages of the squall lines A to E the deep depression mentioned in Section 3 remained almost stationary and centred close to the Faeroes (Fig. 9B).

The first thunderstorm, associated with line A, was reported from the north-west coast of Mayo at 17.30 on the 15th, and was moving north-east. Further thunderstorms, apparently associated with a more southerly portion of line A, took place in Counties Donegal, Mayo and Galway as the squall line moved inland. Almost at midnight a second squall line, B, reached the western coast of Kerry and thunderstorms connected with its passage took place in south-western Ireland, being particularly severe at Cork. Further phenomena which seem to be associated with the movement of this line across southern Britain were a hailstorm in the Wye Valley at 08.00 (on the 16th), thunder at Brackley (Northants.) at 11.05, thunder near Bedford about noon, and a rather severe hailstorm at Cambridge at 13.20.

The third squall line, C, with which were associated the majority of thunderstorms on February 16th, reached Pembrokeshire at 13.45 when a very destructive thunderstorm took place in the southern part of that county. The squall moved across England at a speed of between 30 and 40 miles per hour and thunderstorms marked its passage over a very large area as indicated in Fig. 8. The thunder was particularly severe in South Wales, at Swindon and at Cambridge; from the latter place it was reported that two storms, one from the north and the other from the west, approached simultaneously and it will be noticed that there is a peculiarity in the 18.00 isochronous line in that neighbourhood. At some stations, mainly in the midland and eastern districts, a very pronounced fall in temperature accompanied the storm; the change in temperature between 13.00 and 18.00 is shown in Fig. 9A. At most stations there was very heavy hail for a few minutes, followed by a considerable period of heavy rain, and at many stations the wind almost reached gale force temporarily, but only at a few places did it change its direction. In the cases where a change in direction took place, usually the wind veered suddenly to W but backed gradually to SW again after the storm. Observers at Swansea and Swindon reported that for a few minutes after the thunder the surface wind died down and rain fell from an easterly direction, soon to be followed by a renewal of the SW current. Fig. 9B shows the pressure distribution and winds at 18h.; the barometric situation is one which appears to be particularly favourable for widespread thunderstorms.

The fourth squall line, D, reached Carnarvonshire shortly after 17.00 and thunderstorms occurred in North Wales and northern England as indicated by the isochronous lines in Fig. 8. Thunder occurred again round the Severn Estuary and in Hampshire. The 20.00 isochronous line may be traced across the storm areas for a very great distance. The 19.00 line near the Mersey and Dee

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Estuaries is interesting; it would seem that part of Flintshire had two storms very close together. The passage of storms associated with line D does not seem to have been accompanied by any very great fall in temperature.

The first thunderstorms apparently associated with a fifth squall line, E, occurred in north Devonshire at 23.30, and the latest records received related to a storm in the Channel Islands at 02.48 on the 17th.

It is to be mentioned that the isochronous lines of squall line C do not in most places run at right angles to the direction of motion of the thunderstorms which moved mainly towards the N.E. and E.N.E. It appears that the phenomena accompanying the passage of the storm were usually somewhat similar to those in a line-squall, but that unlike the line-squall, the wind change, if any, in the present thunderstorms was only very temporary. Also, on barograms so far examined the thunderstorm appears to be simultaneous with a sudden "dip" in the barograph "trace" and not a sudden rise in pressure.

The time intervals between the passages of the squall lines at any station were often between three and five hours; the times of occurrence of the two hailstorms and the two thunderstorms in the Forest of Dean area were approximately 08.00, 11.10, 16.05 and 19.45 respectively. This has been noticed also in other groups of storms.

§6. The Hourly Frequency of Winter Thunderstorms.

On the suggestion of Mr. R. G. K. Lempfert the times of occurrence of the thunderstorms in winters 1925 and 1926 were tabulated with the intention of investigating the part played by convection in the promotion of these storms. The country was divided into two main areas, viz., (*a*) coastal regions, (*b*) inland regions; for this purpose, a place more than ten miles from the *open* sea was regarded as "inland." The day was divided into the following four periods:—

I.	7h. to 12h.	Period of	increasing	diurnal	convection.
II.	12h. to 17h.	,,	maximum	,,	,,
III.	17h. to 22h.	,,	decreasing	,,	,,
IV.	22h. to 7h.	,,	minimum	,,	,,

The above divisions of country and time are due to Mr. Lempfert.

Stations were selected so that their distribution over the British Isles should be as even as possible. In cases where it appeared that a storm had not been recorded at a selected station the time of occurrence was inferred from reports from the neighbourhood. The data were first tabulated for each hour, occurrences between, say, 17.30 and 18.30 being included under 18.00; the figures thus obtained were smoothed in threes and expressed as a percentage of the number of storms occurring during the whole 24 hours. The hours were finally grouped into the four periods mentioned above. The results for the first three months of both 1925 and 1926 are indicated in Table III.

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Period of Day (See above).		Coastal Regions.			Inland Regions[3].		
		1925.	1926.	Mean.	1925[4].	1926.	Mean.
		%	%	%	%	%	%
I.	7h. to 12h.	2.8	0.9	1.9	1.5	1.4	1.5
II.	12h. to 17h.	3.7	3.7	3.7	9.0	5.3	7.1
III.	17h. to 22h.	5.7	8.2	6.9	6.0	7.7	6.9
IV.	22h. to 7h.	4.4	4.0	4.2	2.0	3.1	2.5

The means of the hourly percentages for each region are as follows :—

Hour.	1	2	3	4	5	6	7	8	9	10	11	12
Coastal ...	4.1	3.5	3.2	4.1	4.4	**4.5**	3.2	2.6	2.1	1.5	**0.9**	1.1
Inland ...	3.2	2.1	1.5	1.3	1.4	1.0	0.8	**0.7**	1.1	1.7	1.7	2.9
Hour.	13	14	15	16	17	18	19	20	21	22	23	24
Coastal ...	1.7	3.1	5.0	**5.4**	5.6	5.0	7.0	7.9	**8.2**	6.7	5.3	3.9
Inland ...	4.4	7.6	8.8	**9.2**	8.7	8.5	7.7	6.2	4.9	5.2	5.1	4.3

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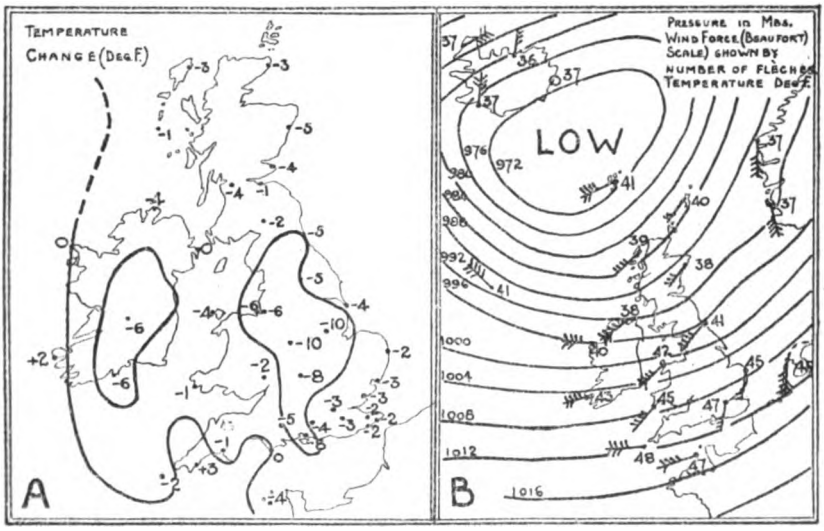

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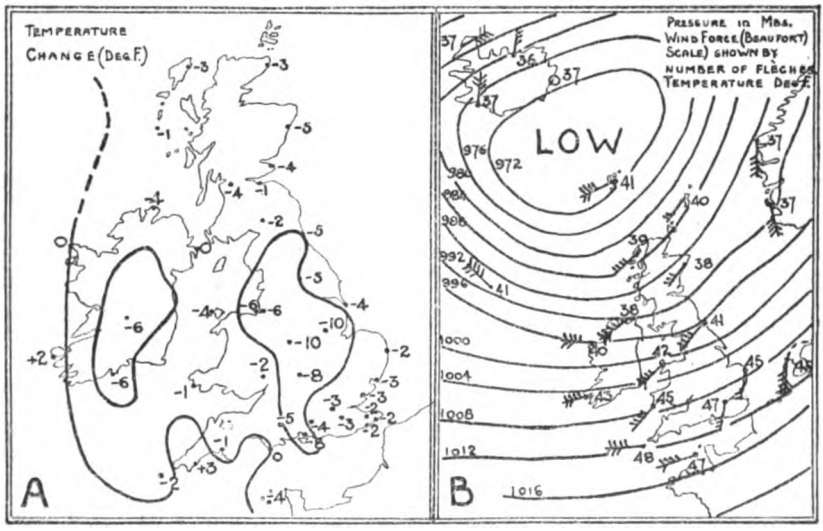

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from the records sent in to me by observers. A comparison of the two sets of maps showed that in England and Wales very few storms had apparently escaped the notice of all the 1,300 thunderstorm observers, but that possibly 25 per cent. of the recorded storms had passed through the meshes of the official network of 300 stations. Also comparisons of records sent in by groups of observers stationed very close together indicated that it should not be expected that any one individual observer could report every occurrence of thunder.

The Effect of Pressure on the Readings of Thermometers.

A few remarks may be of service in connection with a note which appears in the July number, p. 211.

The fact that pressure affects the readings of ordinary thermometers is well-known in accurate thermometric work. Corrections are applied both for external and for internal pressure. When an ordinary mercury thermometer is used in a horizontal position the bulb is exposed to practically no internal pressure, but when used in the vertical position it is exposed to a pressure which is proportional to the height of the top of the mercury column above the centre of the bulb, and so increases directly with the temperature. A mercury thermometer may have its range for high temperature work extended by introducing above the mercury gas at high pressure. In that case the effect of the pressure on the reading may be considerable. If a mercury thermometer is always used in the vertical position, and has been compared in that position at the National Physical Laboratory, the effects of the varying internal pressure are provided for in the certificate. But if such a thermometer is used in the horizontal position a correction is called for. Whether it is sensible or not depends on the length of the mercury column, and the accuracy aimed at. The difference between the external pressures at ground level and at the top of the atmosphere is equivalent to the pressure of about 30 inches of mercury. Except in a very long thermometer the internal pressure will seldom attain a third of this; still it is of the same order as the change of pressure likely to be experienced in air flights.

If we define the pressure coefficients, external (a_e) and internal (a_i), through the equation

$$a = (1/p)(\delta V/V),$$

where p is the pressure which produces a change δV in the volume V of the bulb, the two are connected through the relation

$$a_e - a_i = (1/k),$$

where k is the bulk modulus of the glass composing the bulb. Thus a_e is the larger, but a_i is of the same order.

With ordinary thermometers, under normal conditions, the corrections are usually small, but the change from the vertical to the horizontal position of a mercury thermometer exposed to a summer temperature will usually produce a recognizable change in the reading. A point to notice is that when an ordinary thermometer is used in a liquid the external pressure rises somewhat rapidly with the depth. A mile of sea water gives a pressure of something like one ton per square inch, as compared with the atmospheric pressure of 15lbs. per square inch. The ordinary deep sea thermometer is protected from this by a glass shield, but I once came across a case where an unprotected (maximum) thermometer had been used in a deep boring full of water when the necessary correction was a number of degrees. C. CHREE.

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THE VARIATION OF EDDY VISCOSITY WITH WIND VELOCITY AND SEASON.

A Study Based on Pilot Balloon Observations at Melbourne.

By H. M. TRELOAR, B.Sc.

Communicated by E. KIDSON, O.B.E., D.Sc., F.Inst.P.

[Manuscript received May 12—Read June 15, 1927.]

Eddy viscosity is believed, on both theoretical and observational grounds, to depend on the temperature difference between ground and air and on the wind velocity.[1] In this paper the seasonal variation at Melbourne of the eddy viscosity in the layer between 50 and 150 metres above the ground is discussed and an attempt is made to determine approximately the quantitative relationship connecting eddy viscosity with wind velocity and with the difference of temperature between the air and the ground.

The basis of the method is the assumption that the frictional resistance to the movement of air over the ground is proportional to the square of the velocity and that the coefficient in this relation is a universal constant. The eddy viscosity is determined by comparing the up-gradient of wind velocity with the frictional resistance.

The fundamental equation is

$$\left[c\frac{dV}{dz} \right]_{z=0} = \kappa \rho V_s^2 \quad . \quad . \quad . \quad (1)$$

Here c is the eddy viscosity;
V is the horizontal velocity of the wind;
V_s is the value of V at the "surface" of the earth;
κ is the coefficient of surface friction;
and ρ is the density of the air.

The expression on the left hand side of equation (1) represents, by definition, the rate of downward transfer of horizontal momentum, and the expression on the right represents the frictional force of the wind on unit area.

In Taylor's[2] analysis of Dobson's observations on Salisbury Plain, the level taken for the "surface" of the earth was 30 metres above the ground and the values found for κ were: for light winds .0023, for moderate winds .0032 and for strong winds .0022. For the present paper κ is taken as .0023 and the value adopted for V_s is the wind at 50 metres, reduced by 5 per cent. Judging from Dobson's[3] observations this is equivalent to the wind at 30 metres. The up-gradient $\partial V/\partial z$ was estimated from the difference of velocities at 150 and 50 metres as deduced from pilot balloon observations at heights of 100 and 200 metres.

[1] Richardson, L. F., *Weather Prediction by Numerical Process*, p. 166.
[2] Taylor, G. I., *London, Proc. R. Soc.*, **92** (A), 1916, p. 198.
[3] Dobson, G., *London, Q.J.R. Meteor. Soc.*, **40**, 1914, p. 124.

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Thus the quantity to be tabulated, c/ρ, was derived from the formula

$$\frac{c}{\rho} = 10^4 \times .0023 \times .95^2 \frac{V^2_{50}}{V_{150} - V_{50}} \quad . \quad . \quad . \quad (2)$$

It provides an estimate of the eddy viscosity 100 metres above ground level.

The observations which were utilised were obtained by the pilot balloon method with single theodolite and rangefinder. For each of the 36 months beginning January, 1922, the observations were separated into classes, *a*, *b*, *c* and *d*, according as the velocity at 50 metres was (*a*) 0–3 m/s., (*b*) 3.1–8.0 m/s., (*c*) 8.1–12.0 m/s and (*d*) greater than 12 m/s.

For each class mean values of the wind at 50 metres and the velocity difference between the 50 and 150 metre level were computed. From September to May inclusive, however, cases in which the wind direction was between south-east and south-west were omitted in computing the mean difference of velocity between the two heights, although they were used in deriving the mean velocity at 50 metres. These winds are not steady and the velocity sometimes decreases with height owing to the sea breeze effect. Monthly values of c/ρ for classes *a* to *d* and for all velocities were computed. These results indicated that the viscosity was much the same during each of the three years. Therefore means for the three years were computed for each calendar month for all velocities and for classes (*a*), (*b*) and (*c*). They are set out in Table I. and Fig. 1. Class *d* included less than three per cent. of the total observations, so the eddy viscosities are not given. The mean values of c/ρ for all velocities compare well with those deduced by Brunt and by Åkerblom (using different methods) from Eiffel Tower wind data covering a range in height of 286 metres centred at a height of 160 metres. The respective values[4] for $c/\rho \cdot 10^{-4}$ for summer, winter and the year are: Åkerblom 9.2, 6.5 and 7.6; Brunt 9.3, 6.8 and 7.4; and at Melbourne 9.2, 4.7 and 6.8. The summer and winter periods of Brunt and Åkerblom are presumed to extend over six months.

The influence of wind velocity and temperature difference between ground and air on the eddy viscosity had now been determined. That increasing wind velocity is accompanied by a rapid increase in eddy viscosity is indicated by Table I. Owing to the absence of suitable temperature observations during recent years recourse was had to those made at the Melbourne Observatory during 1858-1863. During this period hourly observations of the temperature of the soil were taken with a horizontal thermometer, the bulb of which was just covered with sand. From the printed results[5] the normal mean difference of temperature between the surface and the air at 10 feet at 10 h., 11 h. and 16 h. was computed for each month. We have denoted this quantity by *T*. The values are given in Table II.; the hours chosen are those nearest the times of pilot balloon ascents at Central Meteorological Bureau, Mel-

[4] Brunt, D., *Dict. of Applied Physics*, Vol. III., pp. 34-35.

[5] Neumayer, G., *Discussion of the meteorological and magnetical observations made at the Flagstaff Observatory, Melbourne, during the years* 1858-1862, pp. 45 and 96.

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TABLE I.—Variation of Eddy Viscosity with the Wind Velocity at a height of 50 metres.

Velocity.		Values of c/ρ 10-4 × C.G.S. Unit. Melbourne, 1922-1924.												
Range of V_{50}.	Mean Value of V_{50}.	Jan.	Feb.	Mar.	April.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
m./s.														
0—3.0	1.9	2.7	2.7	1.2	3.7	1.0	1.5	1.5	1.5	1.2	3.7	6.8	2.1	2.5
3.1—8.0	5.5	9.7	10.2	5.6	6.6	3.9	3.7	3.7	3.3	5.8	6.2	5.4	9.3	6.1
8.1—12.0	9.7	20.6	17.8	15.7	11.0	6.6	6.6	9.1	8.1	7.5	9.1	10.4	25.0	12.3
All observations ...	5.9	11.2	10.3	6.6	6.2	3.9	3.9	4.3	4.1	6.0	7.0	7.6	11.0	6.8

TABLE II.—Variation, with Wind Velocity, of the Difference between Air and Soil Temperatures.

			Soil Temperature minus Air Temperature (Deg. F.), Melbourne, 1858-1863.											
			Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1858	T_m	Max. Soil—Max. Air . . .	19.0	26.0	17.7	9.6	3.3	2.2	3.8	8.2	11.3	20.3	28.3	22.6
	T	10, 11 and 16h. All observations .	17.0	16.0	13.7	6.5	2.1	0.8	1.1	3.4	6.4	11.0	16.1	17.6
1858	T_V (a)	,, ,, Wind Force, 0—3 .	21.1	19.7	13.8	7.7	3.0	1.1	1.4	5.7	10.4	15.2	25.6	21.0
to	T_V (b)	,, ,, ,, ,, 3—5 .	19.3	18.5	12.7	6.6	2.0	0.6	1.0	4.9	7.3	11.7	16.6	17.8
1863	T_V (c)	,, ,, ,, ,, 6—8 ,	13.6	12.5	8.2	4.0	1.7	0.1	1.0	1.2	5.8	8.2	14.2	18.2

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bourne. Readings for each day when hourly temperatures were taken not being available, the normal monthly temperature differences for the velocity classes *a*, *b* and *c* could not be estimated directly, but rough values were derived by the following method.

For the year beginning March, 1858, there were published,[6] for each day, the maximum soil and air temperatures, and the surface wind velocity according to a wind scale then in use. The initial difficulty of deciding what ranges of the maximum surface wind coincided with the classes of the wind at 50 metres *a*, *b* and *c* seemed to be best met by using the frequency of observations as a guide. The classes, 0–3, 3–5, 6–8, the numbers being those on the surface wind scale, included respectively 35, 61 and 20 per cent. of the observations, whereas the percentages for the classes *a*, *b* and *c* were 19, 57 and 21. These classes were therefore assumed to correspond. The large number of observations with surface wind velocity of force 3 necessitated the overlapping of the first two surface wind classes.

The monthly normal temperature difference for a particular velocity class was denoted by T_v, the mean monthly difference of maximum temperatures by T_m and the corresponding quantity for a particular velocity class by T_{mv}.

For the three surface wind classes monthly means of T_{mv} were computed for the year March, 1858-February, 1859. Estimates of the monthly normals T_v were deduced by assuming equality of the ratios $T_{mv}:T_m$ and $T_v:T$. The monthly means of T_m for the year beginning March, 1858, and the deduced values of T_v for the years 1858-1863 are included in Table II.

Corresponding values of eddy viscosity, wind velocity at 50 metres (V_{50}), difference of temperature between soil and air (T_v) have now been obtained for different groups. Fortunately the ranges of the three variables are sufficiently great to bring out their mutual relation, which is in fair accordance with the following equation:—

$$c/\rho = 70\, V_{50} + 7\, V_{50} T_v \quad . \quad . \quad . \quad (3)$$

The values of c/ρ derived from wind observations are compared with those computed from the above equation in Fig. 1. The agreement is good, considering the nature of the observations, except for the highest viscosities.

According to equation (3) the annual variation of eddy viscosity for a constant wind velocity is determined by the annual variation in the difference of temperature between surface soil and air. It is considered that there is a physical relation between the two variables. It should be noted that while the annual variations of *c* and *T* closely resemble each other, they differ from those of other quantities which might be thought to be responsible for variations in eddy viscosity. Both the surface soil and the air temperature, for instance, reach their minimum in July. The difference of temperature between soil and air, however, is lowest in June and is not much higher in May, and this is reflected in the eddy viscosity which first reaches a minimum in May (Fig. 1). The annual

[6] Neumayer, G., *Discussion of the meteorological and magnetical observations made at the Flagstaff Observatory, Melbourne, during the years* 1858-1863. Mannheim, 1867. Pp. 6-51.

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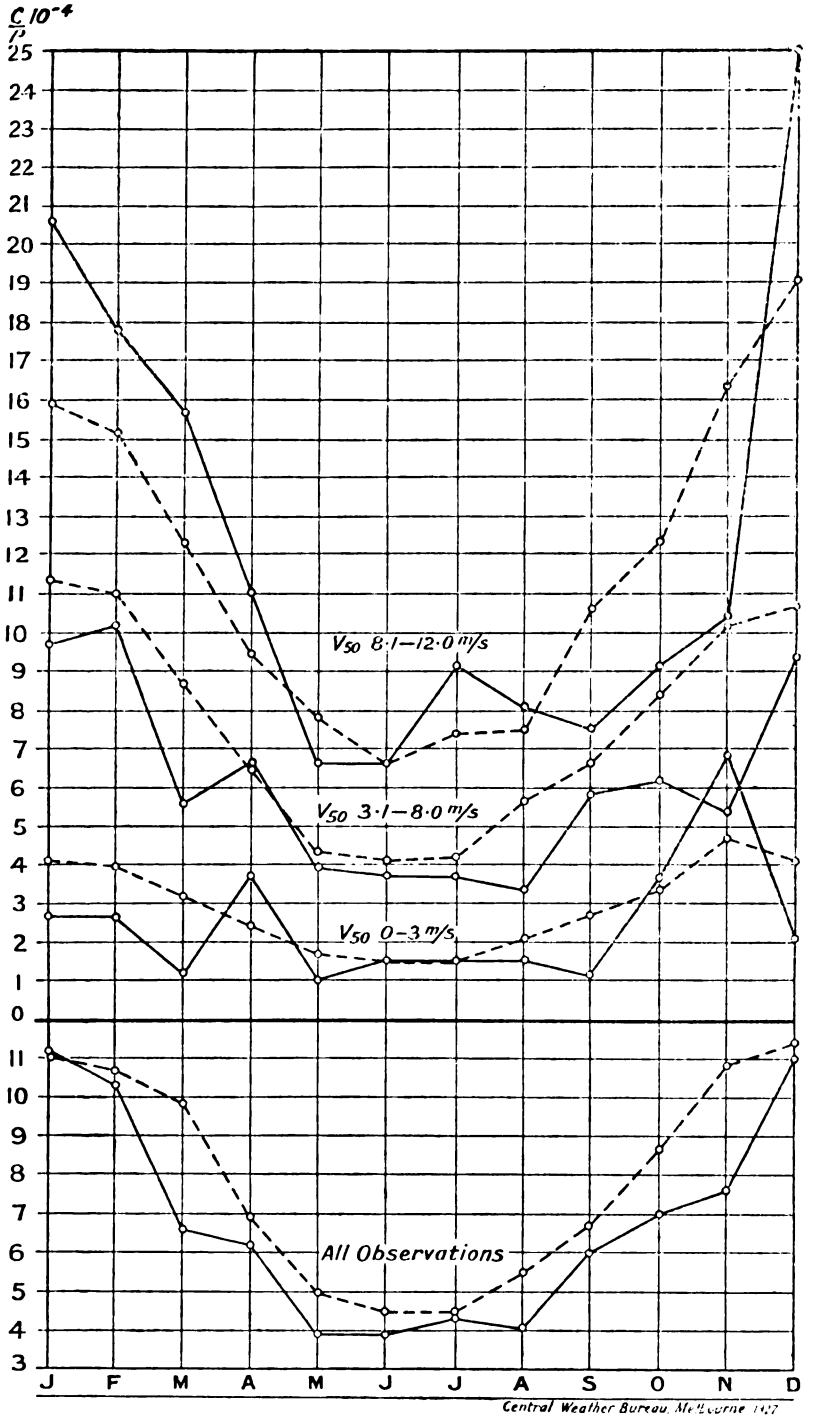

FIG. 1.—Values of c/ρ computed from the empirical equation

$$c/\rho = 70V_{50} + 7V_{50}T_V$$

compared with those derived from the actual wind observations.

———— Mean values of c/ρ at 100 metres height at Melbourne.

— · · — — c/ρ computed from empirical equation.

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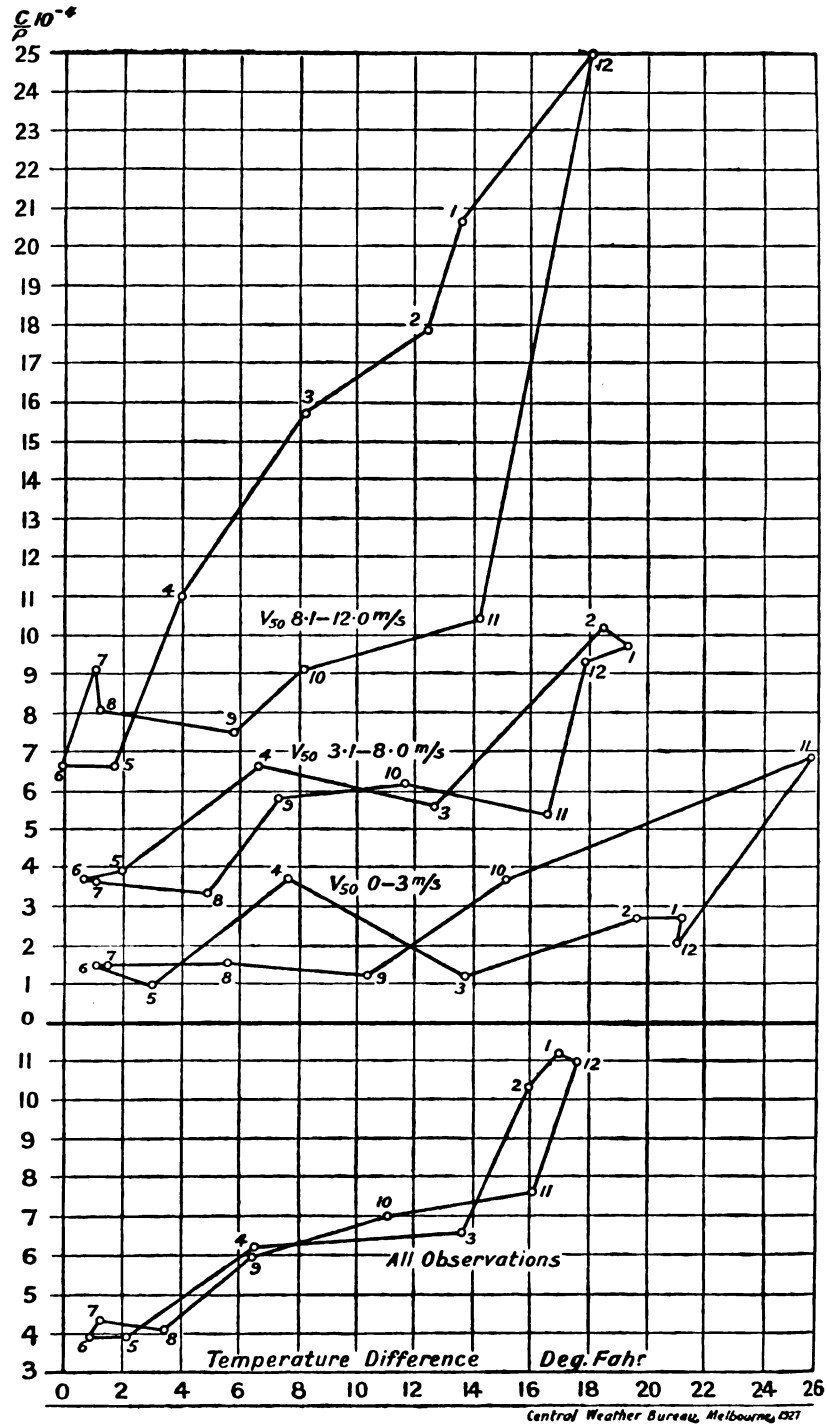

FIG. 2.—Relation between eddy viscosity and the temperature difference between the soil and the air at 10 feet. (Numerals on graphs refer to months of year).

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variation of the amount of solar radiation, however, which has extremes in January and June, is very similar to the annual variation of T.

The relation between c/ρ and T is shown in Fig. 2. The curve for the highest velocity class indicates that for the same values of T and V_{50} the eddy viscosity is higher from February to April than from September to November. Inspection shows that this is not due to differing frequencies of winds from the sea during the two periods and it cannot be attributed to differing lapse-rates over the first kilometre, because the lapse-rate would be expected to be higher in the spring than in autumn. Whatever the cause, this effect should be taken into account in endeavouring to find a more refined relation between the eddy viscosity and the factors which control it.

To the Commonwealth Meteorologist, Mr. H. A. Hunt, my acknowledgments are due for facilities which made this study possible.

SUMMARY.

The eddy viscosity (c) is that defined by Richardson, such that cdV/dz is the downward flux of horizontal momentum in a fixed azimuth. A simple method of determining mean values of c is discussed. The seasonal variation of c at a height of 100 metres at Melbourne for different wind velocity classes is given. The eddy viscosity is found to be represented fairly well by the empirical equation

$$c/\rho = 70\,V + 7\,VT$$

where V is the wind velocity at a height of 50 metres, T the difference of temperature in degrees Fahr. between surface soil and air at 10 feet and ρ the density of the air.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 18, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society :—

GEORGE ARTHUR BULL, B.Sc., 159, Harbut Road, S.W.11;

NEVILLE DUNCAN BURLEIGH TAYLOR, Com. R.N., H.M. Navigation School, Portsmouth.

June 15, 1927.

At the *Ordinary Meeting* the following were balloted for and elected Fellows of the Society :—

RAYMOND FREDERICK BUDDEN, 61, Wilton Road, Salisbury, Wilts;

JAMES CLELAND, Briarwood, Gorway, Walsall, Staffs.;

ALEC EDWARD MARRIOTT DODINGTON, Lieut. R.N., 29, Wetherby Mansions, S.W.5;

ADOLPHUS W. H. GOSS, The Old Villa, Alsager, near Stoke-on-Trent;

JOHN ARTHUR RODWELL, Glen Lea, Nelson, Lancs.

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CORRESPONDENCE AND NOTES.

Memoirs of the Royal Meteorological Society.

In the early part of 1926 it was announced in the *Journal* that the Council had arranged to publish those papers involving highly technical methods of description in a separate series entitled *Memoirs*.

This arrangement has been carried into effect and up to the present date eleven separate *Memoirs* have been issued, while others are in course of publication. These *Memoirs* are forwarded free of charge to Fellows of the Society should they express a desire to receive them. The number so far issued is not very large and those Fellows who do not receive them and would like to have copies are asked to communicate with the Assistant Secretary.

Nephoscope Observations at Mauritius.

A Marvin Nephoscope was in use at the Royal Alfred Observatory, Mauritius, from 1904 to 1910, and the results of the observations are printed in the Year Book of the Observatory for those years.

The first table shows the frequency of occurrence of winds from the specified directions as given by observations on cirrus clouds and altocumulus clouds. If two observations on the same type of cloud were made on one day that made nearest noon was used. The third line shows the frequency of wind directions taken from hourly readings of the anemometer. The number of hours of calm was only 11 out of 61268 hourly readings. The observations were first made out month by month, but no appreciable annual variation was apparent in the form of the frequency curves of the cirrus directions or the surface winds, although owing to the scarcity of observations of cirrus in winter, June to September, it is not justifiable to state that there is no annual variation. An apparent variation in the altocumulus observations will be discussed later, but in the table below and in Fig. 1 all the observations are massed together.

TABLE I.—PERCENTAGE FREQUENCY OF WINDS UNDER SPECIFIED DIRECTION.

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Cirrus ...	1.3	0.5	0.9	0.1	0.0	0.4	0.4	0.3	0.8	2.4	3.9	15.8	28.6	28.4	11.2	5.0
Al. Cu. ...	5.7	5.4	11.6	18.6	6.7	2.2	1.8	2.2	2.3	2.1	3.3	3.1	6.9	10.6	9.8	8.3
Surface ...	1.3	1.9	3.3	11.3	24.8	34.0	11.0	3.5	1.6	0.8	0.8	1.2	1.1	0.8	1.1	1.3

The total number of observations used was :—Cirrus 393; Altocumulus 487; Surface 61268.

The cirrus and surface observations bring out in a very striking way the persistent so-called Antitrades between W. and W.N.W. and the trades between E. and E.S.E. The double peaked altocumulus curve presents a very curious problem. (*a*) Altocumulus may form near the calm region separating the two currents sometimes in the one current sometimes in the other, so that the two peaks represent the individual peaks of the cirrus and surface curves displaced through a few points. If we accept the usual estimate of the height of altocumulus as about 5 kms. this curve cannot be reconciled with the results of pilot balloon ascents made in Mauritius[1] in which the junction between the westerly and

[1] Walter. Results of observations on the direction and velocity of the upper air current over the South Indian Ocean. *Meteorological Office, Geophysical Memoir*, No. 39.—In the press.

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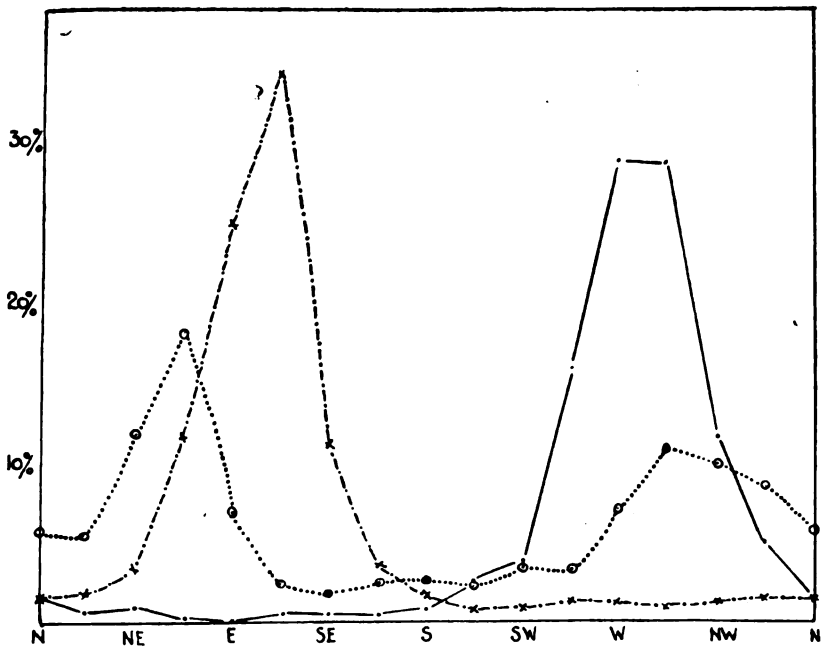

FIG. 1.—Percentage Frequency of direction, Cirrus •————• Altocumulus o - - - o Surface x— - — - —x

easterly currents was usually found at a height of about two kilometres. (*b*) Two different types of cloud may be represented under the heading altocumulus, one occurring usually in the upper current and the other in the lower. It is possible that classification of altocumulus and stratocumulus presents exceptional difficulties here, for on one occasion already in the writer's short experience two clouds were present, one moving east and the other west, either of which in the absence of the other would have been classified as typical altocumulus. It was, however, evident that the cloud moving from the east was very much lower than the other. This is in the writer's opinion the true explanation of the two peaks, so that the left side of the curve represents the wind frequency at about 1½ kilometres and the right side of the curve the frequency at about 5 kilometres. If this is true, there is a decided annual variation in the prevalence of the two types of cloud as shown in the following table :—

TABLE II.—PERCENTAGE OF ALTOCUMULUS CLOUDS HAVING SOME WESTERLY COMPONENT.

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
50	65	60	61	86	64	35	25	22	13	41	50

CIRRUS MOVEMENT ABOVE A TROPICAL CYCLONE.

No daily synoptic chart is available for the South Indian Ocean, but the tracks of tropical cyclones are made out as far as possible and published from time to time in the Year Book of the Observatory. The

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following diagram shows the result of plotting cirrus observations with reference to the centre of those cyclones which passed within 600 nautical miles of Mauritius.

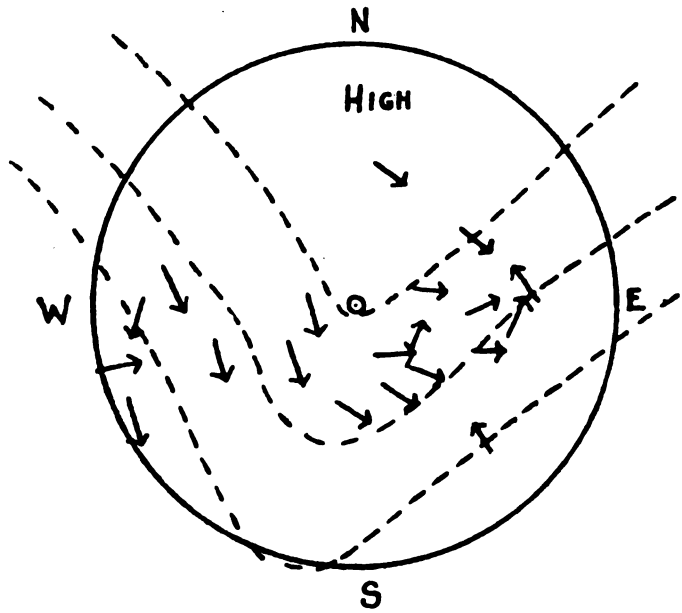

FIG. 2.—Cirrus observations with reference to the centre of a cyclone. The circle is 600 nautical miles radius. The broken lines represent isobars at the cirrus level.

It will be seen that there is distinct evidence of an anticyclonic circulation in the cirrus levels above a cyclone. The circulation may not in general be closed so that the anticyclone is of the nature of a V-shaped wedge protruding southwards from the permanent equatorial high as in the isobars drawn. The unfortunate absence of observations in the northern half of a cyclone is due partly to the prevailing low cloud when a cyclone is near the south of the island and partly to the fact that tracks cannot in general be followed far to the south owing to lack of observations. It must be pointed out that, although on those occasions when two cyclones were known to exist in the neighbourhood the observations were not used, there may have been unsuspected cyclones at times, for in unsettled periods, cyclones frequently occur in twos or threes.

R. A. WATSON.

Aerological Station,
Vaccas, Mauritius.
July 30, 1927.

On the Unit of Radiation used in Meteorological Treatises on Actinometry.

This question has recently been brought into discussion by Sir Napier Shaw in his excellent *Manual of Meteorology*, where he wishes to replace the unit hitherto commonly used, namely *gramme calorie per square centimetre* with *kilowatt per square decametre*. This unit has also, at least to some extent, been adopted by H. H. Kimball in his very valuable

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survey on actinometric data published in the *Monthly Weather Review* for April, 1927.

To the present author it seems to be a very serious step to leave the uniformity of units, which hitherto has been a favourable characteristic of actinometric works of almost all countries, in order to introduce a duplicity of units, which necessarily will follow as a consequence if the proposal of Sir Napier Shaw obtains adherents. I cannot find that the disadvantages thereof will be balanced by corresponding advantages.

In all the classical works by Langley, Knut Ångström, Abbot and Fowle, Dorno and others, the unit commonly used has been the gramme calorie per square centimetre, and it is highly important that the results of later investigators should be easily compared with the work already done without troublesome computations and reductions.

Further, it seems that in this case the gramme calorie is the most natural and logical unit. In all measurements of radiation within meteorology, the radiation is transformed into heat and not into electrical energy and the adopted unit of heat energy is the gramme calorie. In this point I perfectly agree with the views of Mr. W. H. Dines, who in discussing this matter with Sir Napier Shaw in *Nature* of August 6, 1927, says: "Also the gramme calorie lends itself very readily to the expression of the first result of radiation, namely to changes of temperature; thus by easy mental arithmetic the thickness of ice that can be melted, or of water that can be evaporated, or the change of temperature of a given layer of air is readily calculated."

This is certainly true. Against this we have the argument of Sir Napier Shaw that "the kilowatt is the unit that engineers use to represent electrical power; solar energy is thereby brought into the same category as the energy which men buy or sell."

It may be readily admitted that in popular treatises or in publications where it is aimed at the interest of certain groups of readers it sometimes may be of value to introduce other units than those commonly used in scientific papers. But this seems to me to be no reason why a scientific and logical unit commonly used should be abandoned.

The chief aim is here *uniformity*. Whether one or the other unit is used, seems of minor importance, as long as the one can be obtained from the other simply through multiplication with a reduction factor. The only way to secure uniformity is to adhere to the unit commonly used in actinometric investigations, namely the gramme calorie per square centimetre.

ANDERS ÅNGSTRÖM.

Stockholm, *August* 28, 1927.

The memorandum which has been communicated to the Society by Dr. Simpson at Dr. Ångström's request was also communicated to me as President of the Meteorological Section of the International Union for Geodesy and Geophysics by Dr. Wallén, Director of the Meteorological and Hydrographical Institute of Sweden. It was intended for the meeting of the Section which was held at Prague, September 3rd to 10th of this year. Dr. Wallén asked that it should be printed in the minutes of the meeting although it had failed to reach him at Prague, and only reached me after my return to London. I have asked the Secretary to include it as an Appendix to the report of the meeting.

The subject of units of measurement only came before the Section in

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the form of a resolution asking the Bureau to make a report to a future meeting upon the unitary systems and practices of the sciences, geodesy, seismology, terrestrial magnetism and electricity, meteorology, oceanography, vulcanology and hydrology, the seven sciences which are included within the scope of the Union. The conjunction of the seven in one Union makes an inquiry of that kind possible and useful.

Dr. Angström's memorandum does not refer to so wide a field; it concerns itself merely with kilowatts per square decametre which I have employed for radiation in many publications, including a survey of solar radiation all over the globe in the Procés-Verbaux of the meeting of Madrid in 1924. I have therefore supplemented his memorandum by a note which is intended to explain that no one could be more cordially in sympathy with Dr. Angström's aspiration for uniformity of units for solar radiation (and every other physical quantity employed in meteorology) than myself. The difference between us is simply a question of how uniformity can most speedily be secured.

Policy will, I believe, be on my side, and history will bear me out in claiming that *a common system of units for the science* should be the first consideration of all those who are desirous of securing uniformity in units. Community of system is more important than uniformity in any single arbitrary unit. My preference for kilowatts per square decametre for radiation as compared with gramme calories per square centimetre per minute or per day, is chiefly that the first belongs to a system based upon energy and its conservation, while the second is purely arbitrary. That there are other advantages I can easily show, but its place in a system is its chief recommendation. There must be many meteorologists who agree with me on that point.

Dr. Angström would apparently regard the units adopted by the pioneers in any subject of measurement as binding upon the science for all time. With all respect for the pioneers I cannot agree with that view, and I do not think other meteorologists can. It is too double-edged. Would anyone, for example, expect to be listened to now if he claimed that the units employed by G. S. Ohm in the enunciation of his law, or by Faraday in his experimental researches on electricity, were binding on physicists and chemists for all time? Does not the science of physics, and do not electricians all over the world, whether they are specially concerned for science or not, owe an immense debt of gratitude to Gauss, Maxwell, Kelvin, Fleming-Jenkin and others who formulated a system of units which enabled students to interpret Ohm's measurements and Faraday's researches in systematic units? Where would electricity be now if systematic units had been vetoed in the middle of the last century in favour of the Daniell's cell or the Siemens unit of resistance?

And thereby may I hang a tale about the power of system in obtaining uniformity. The founders of systems of units had to conciliate opposition by framing two alternative *systems*, the foot-grain-second and the centimetre-gramme-second. My earliest practice with measurements of terrestrial magnetism was in foot-grain-second units. British magneticians were prepared to accept a system but not one based on metres and grammes. The foot-grain-second system is now only a memory and for magnetism the C.G.S. system is universal.

My own prepossession in favour of systematic units for meteorology dates from 1910 when I became responsible for publishing other geophysical data with the meteorological output of my Office, data for terrestrial

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magnetism in properly ordered C.G.S. units and those for meteorology which up to that time had appeared in the happy-go-lucky units of the pioneers, like the gramme calorie per square centimetre per minute. I am apparently more subject to scientific nausea in circumstances of that kind than some of my colleagues; but I spent twenty years of my life in instilling the principles of experimental physics into the studious youth at Cambridge, and the endeavour to be logical and reasonable about physical questions for twenty years had perhaps left its mark on my constitution. I sought, therefore, and obtained, from the Gassiot Committee of the Royal Society, permission to use systematic units for meteorology as well as magnetism. Solar radiation was accordingly expressed in watts per square metre. That was sixteen years ago, and the audacity of myself and my advisers has apparently escaped public notice until now.

I admit that the endeavour to convince meteorologists that a system of units is one of the primary requirements for progress in the science is not only arduous in itself, but is also faced with many discouragements. In the isolation of the presidential chair of an international meeting when one catches the suggestion of opinion from this side and from that upon subjects in which one is personally profoundly interested, systematic measurement is apt to carry the appearance of a hopeless quest. So many considerations which seem to be remote enter into the crystallization of opinion. And yet somehow, when the votes have been taken, systematic meteorology has secured surprising and almost unexpected successes. Quite recently at Leipzig systematic units repeated the record which they secured in London two years ago and that will continue. "I am personally in favour of it, but as representative I cannot vote for it" was one form of opinion in 1925; there is less feeling of being thought too much in advance of the age now.

Much, of course, is owing to the work on Dynamic Meteorology and Hydrography by V. Bjerknes and his collaborators. It lays the foundations of systematic meteorology and the appeal of the work on that basis is, to me at least, irresistible. Some day I should like to translate some of its formularies in terms of temperature and entropy and bring into greater prominence the idea of temperature as the "velocity of mean square," but that will not impair its systematic nature.

Dr. Angström applauds Mr. Dines's critical attitude towards kilowatts per square decametre, but what about a gramme calorie per square centimetre per day? I will leave them to settle what exactly radiation expressed in gramme calories per day may mean; I always have to look it up when I want to know; and also whether a minute or a day is more nearly in accordance with systematic scientific practice. It is the gramme calorie which unites the opposition to a systematic unit; but here I am on safe ground. The gramme calorie is surely a survival of the middle nineteenth century and is not suitable for the twentieth. It echoes a claim to express the total amount of heat as a product of the amount of water warmed and the rise of temperature produced. I happened to live a good deal of my academic life among people who were using electrical methods to determine the dynamical equivalent of heat, and one of the lessons I carried away was that to regard the specific heat of water as constant was to be behind the times. Of course, the difference does not matter much, but it is just that kind of precision of idea which distinguishes and ought to distinguish the twentieth century from the nineteenth.

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And the suggestion that raising the temperature of water by radiation finds quantitative application in nature leaves me quite cold. If the sun shines on the sea or moist earth, to imagine the process as effectively limited to the warming of water or earth is really too crude for modern purposes. The concentration of solar radiation necessary to cook a chop is much more likely to be expressed in kilowatts per square decametre than in gramme calories per square centimetre per minute. And in practice the kilowatt per square decametre is exceptionally convenient as a glance at my table of radiation in the Procès-Verbaux of Madrid will convince any impartial reader. It gives the solar constant in three figures about 145 without a decimal point. What more can one want?

I have heard it rumoured that Dr. Abbot disapproves of kilowatts per square decametre as a unit for solar radiation. I wonder if those of us who are in favour of systematic measurements could persuade him that in this particular he is mistaken. His purpose, with which we all sympathise, will best be served by getting his measurements incorporated into everyday use in all the many sciences which are concerned with solar radiation. That will be the easier the more widespread the practice of using a systematic unit to express energy of any kind. In solar physics as in climatology so long as we are dealing only with geographical or chronological comparisons an unrelated arbitrary unit is as good as another; but when it comes to crossing scientific frontiers a negotiable unit is the best passport.

I am myself convinced that in a science like meteorology which makes use of almost every other science under the sun the passport of systematic units is an absolute necessity for progress. I may not live to see it, but the time cannot be far distant when that principle will be recognized even by Ministers for Air, and as soon as they are systematized our units will have become also uniform.

NAPIER SHAW.

10, Moreton Gardens, S.W.5,
31st October, 1927.

Meteorological Observations taken during the Solar Eclipse of June 29, 1927.

A very complete set of observations taken during the eclipse of June 29, 1927, has been received from Mr. R. Francis Granger, the results of which are set out in the following table (Table I.). The wet and dry thermometers used were exposed in a standard Stevenson screen. The grass minimum thermometer was exposed one inch above short grass shaded from direct sunshine, while the black bulb thermometer (not *in vacuo*) was freely exposed to sun and wind 3ft. 6in. above ground level. The barometer readings were taken from a standard Kew pattern instrument hung in the open air but shielded from the sun, and wind observations were made from a sensitive arrow set 30ft. above the ground.

1. PRESSURE.

As will be seen from the accompanying table, there is, superimposed upon the general fall of pressure which occurred during the period, a slight maximum at about maximum phase (06.23 B.S.T.) with a minimum value both just before and just after. The variation on a smoothed curve approximating to the 0.2 mb. occurring at Stockholm[1] (1921 eclipse) and which was also noted by Mr. Granger during the same eclipse.

[1] Barlow, E. W., Meteorology of Solar Eclipses, *Q.J.R. Meteor. Soc.*, **53**, 1927, Supplement p. 8.

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TABLE I.—METEOROLOGICAL OBSERVATIONS TAKEN AT LENTEN FIELDS, NOTTINGHAM, 52° 56′ N, 1° 13′ W, DURING THE SOLAR ECLIPSE OF JUNE 29, 1927.

Time.	Pressure M.S.L.	Rel. Hum.	Vapour Pressure.	Temperature.				Wind direc. and force.
				Dry Bulb	Wet Bulb	Black Bulb.	Grass Min.	
B.S.T.	mb.	%	mb.	°F.	°F.	°F.	°F.	
4.15	1007.34	95	11.2	48.8	48.2	48.0	47.8	—
4.30	1007.34	95	11.2	48.7	48.1	48.0	47.8	—
4.45	1007.27	95	11.2	48.7	48.1	48.0	47.0	—
5.00	1007.09	97	11.3	48.3	48.0	47.6	46.3	—
5.15	1006.98	97	11.2	48.2	47.8	47.9	47.0	—
5.30	1006.93	97	11.2	48.2	47.8	47.8	47.1	SW'S2
5.45	1006.90	95	11.2	48.9	48.2	49.3	47.9	SW'S2
6.00	1006.65	95	11.2	49.0	48.3	49.0	47.9	SSW1
6.15	1006.67	93	10.9	48.6	47.7	48.4	47.0	SSW1
6.30	1006.67	93	10.8	48.3	47.4	48.0	47.8	S, 1
6.45	1006.62	92	10.6	48.2	47.2	48.6	47.0	—
7.00	1006.47	92	10.7	48.3	47.3	49.1	48.0	S'W1
7.15	1006.28	92	10.8	48.8	47.7	51.0	48.8	—
7.30	1006.25	89	10.6	49.4	47.9	51.2	50.0	S'W1
7.45	1006.17	88	10.8	49.9	48.3	52.2	51.0	SSW1
8.00	1006.07	87	10.9	50.5	48.7	54.8	51.8	SSW2
8.15	1006.00	85	10.7	51.1	48.9	56.1	51.9	SSW2
8.30	1005.72	81	10.8	52.4	49.5	59.1	54.0	SSW3

2. TEMPERATURE.

Temperature varied less than in 1921 when a fall of 3°.6F. was noted, but then the eclipse occurred when the temperature was rising fast, while on this occasion the diurnal rise did not begin until after the eclipse had commenced and, too, radiation was checked by cloud layers.

3. WIND.

Surface winds backed a little in direction and decreased in force at the time of maximum phase, but both the lower and upper clouds maintained a constant direction.

4. CLOUDS.

The lower clouds, which were of an unstable type during the earlier phases, at 06.15 became denser and were no longer broken but lay in a continuous hazy sheet and by 06.48 all detail was disappearing. At 07.15h. they became lumpy again, and at 07.30h. the upper cloud which had undergone a similar change became, too, more definite and broken.

A shorter series of observations has also been received from Mr. E. Nimmo, Broadstone, Dorset. With him the temperature (from a thermometer exposed on a north wall) fell from 54°F. to 51°F.—one degree below the night minimum—and the grass thermometer sank to 49°.5F., at the time of maximum phase, equalling the previous night's minimum, but the surface wind, SW force 4 at the beginning, veered to WNW force 4 at maximum phase and then backed again, becoming WSW force 2 at the end of the eclipse. This change in the wind direction was also shown in the movement of low stratus cloud present during the period.

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OBITUARY.

SURGEON-GENERAL H. COOK, I.M.S., M.D., M.R.C.S.

The death of Surgeon-General Henry Cook, I.M.S., M.D., M.R.C.S., etc., one of the oldest fellows of the Society, occurred at Lee-on-Solent on May 30, 1927.

He qualified as M.R.C.S. Eng. 73 years ago, having been a student at St. Mary's and St. George's Hospitals. He, then, joined the Indian Medical Service and served with the Persian Expedition of 1857 and with the Abyssinian Expedition of 1867-8. He was, at one time, Principal and Professor of Medicine and Hygiene at Ewart Medicine College, Bombay, and Dean of the Faculty of Medicine at Bombay University.

He was elected a Life Fellow of this Society in 1870.

REVIEWS.

Environment and Race. A study of the Evolution, Migration, Settlement and Status of the Races of Man. By GRIFFITH TAYLOR. Oxford (University Press), London (Humphrey Milford), 1927. 8vo. Pp. xv + 354, pls. 6. 21s. net.

This really consists of two quite separate books, one purely anthropological, and the other widely geographical. The anthropological section (part I., Introduction, part II., The past) maintains two theses; first that the evolution of *Homo sapiens* has been accompanied by a steady broadening of the head, brachycephalic or "Alpine" races being the latest product and extremely long-headed races the earliest types. The second thesis is that this evolution has proceeded mainly in the central Asiatic region, where the broadest heads are found at present, and that the earlier stages have been successively thrust out from the central home into the three "peninsulas" of America, Africa and Australasia. It is suggested that the main migrations have been connected with the last three of the great glacial stages, Neandertal man after the Mindelian, the earliest Iberian races, including Cro-Magnon man, after the Rissian, and the later Iberians and early Alpine-Mongolians, the union of which produced the Nordic race, after the Wurmian. One notes in passing the author's somewhat strange generalisation of the early Palæolithic men of Neandertal, Rhodesia, China, Java and Queensland into a Proto-Australian race on the direct line of human evolution, which conflicts with the orthodox view that most of these early races are offshoots from the human stem, not on the direct line of evolution of *Homo sapiens*.

There are a few other points in this part of the book which one could wish the author to modify. Thus in the maps of Africa on page 97 the eastern and central parts of the equatorial zone are shown as drier during the Wurmian than they are to-day. There is no evidence for this, rather the reverse, as E. J. Wayland has shown in the Uganda geological reports. The Quaternary is not limited to the post-glacial period, as stated on pages 132-133. On page 233 we are told that the fairly uniform warm climate of the Early Tertiary was *no doubt* partly due to considerable changes in the earth's eccentricity and in the inclination of the axis.

The geographical half of the book is of greater meteorological interest. Part III., the Present, deals almost entirely with problems of settlement in Australia. It is explained that "the chief aim of these

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chapters is to focus attention on those portions of Australia which will best repay exploitation, and to arrive at definite conclusions as to the relative merits of various regions on the continent." The chief conclusion is that the possibilities of Australia have been greatly overrated, and that the nearest approaches to the climate of large areas of the continent are to be found in parts of the world which are not usually regarded as favourable. If one superimposes Australia on northern Africa, latitude for latitude, one finds that it extends practically from Gibraltar across the Sahara to Southern Nigeria, and this gives a fair idea of its climate and vegetation. The economic possibilities of the south-eastern coastal areas are undoubted, but most of the interior has such hot summers and scanty unreliable rainfall that it will never be thickly populated. Quantitatively, the author regards habitability (apart from exploitation of minerals) as a function of rainfall (amount, seasonal distribution and reliability), evaporation and temperature, and he constructs a chart which shows that more than half of Australia cannot support three people to the square mile, and a considerable area cannot support even one.

There is a great fascination in speculating about what is to come, and accordingly the greatest interest will be reserved for part IV., the Future, which attempts to measure the capacity of the globe to support a white population. The author's work, though independent of that of Ellsworth Huntington in *Civilisation and Climate*, arrives at rather similar conclusions. The factors of habitability are taken to be four, mean annual temperature, with an optimum at 53°F. and limits of habitability at 30° and 70°, rainfall with an optimum at 40 to 50 inches a year, coal supply, and suitability of location, the latter expressed in terms of elevation, with the lowest regions the most favoured. These four quantities are ingeniously employed as the framework on which to construct a four-sided figure; the area which this figure includes is the habitability of the region for white races. The results suggest that the greatest habitability lies in North America, towards which the centre of population and of power will inevitably shift, until the United States alone, with a population of 513 millions, outweigh the whole of the British Empire. In another 200 years or so the world will be fully populated, and the author foreshadows "a vast world-struggle between higher civilisations with a low birth-rate and lower civilisations with a high birth-rate."

C. E. P. B.

Wetter und Wettervorhersage (Synoptische Meteorologie). By Dr. A. Defant. Second completely revised edition. Franz Deuticke Publishing Company: Leipzig and Vienna, 1926. 346 pages with 154 illustrations. 18 Gold Marks.

Professor Defant's original book on the above subject was a product of the war years. Comparing it with the present work, one cannot but be impressed by the results which have accrued from less than a decade of research and co-ordination in the province of meteorology. Research itself had certainly been increasingly pursued for over a century, but, without the stimulus to co-ordination born of war time exigencies, recent meteorological progress must have been along a much more leisurely path.

This book itself illustrates what can be achieved by co-ordination in a subject whose many ramifications are apt to sidetrack the student. It gives a fairly complete and concise account of our present knowledge of weather science with a view to its use as a basis of forecasting, without the prosy and vague digressions so frequently encountered in the literature of an inexact science.

Professor Defant classifies his subject into three main divisions.

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The first, which occupies roughly two-thirds of the book, develops the subject of the weather map from the earliest isobars down to these favoured days of wireless communication, and in so doing gives a comprehensive account of meteorological symbolism, conventions and laws requisite for its appreciation. In addition, opportunity is taken at various stages throughout the seven chapters of this section to introduce and outline those theories, chiefly based on comparatively recent research, which are bound up with the interpretation of the weather map and associated upper air phenomena.

"Frontenmeteorologie" is fully discussed and considerable space given to the work of Bjerknes and Solberg. Reference to the exhaustive analysis of Bergeron and Swoboda into the movements of an extensive front which established itself over the Atlantic and Europe along 50°N. latitude in October, 1923, brings this modern aspect of weather science up-to-date. Early theories of the cyclone and anticyclone are not neglected however, and one feels that the author has endeavoured to combine the older and the newer viewpoints into one complete exposition.

The second section consists of four chapters on forecasting. The first two of these are a more or less general treatment of the problem. Following a reference to Richardson's work on prediction by numerical processes, the value of local observations is discussed and a method with a climatological basis is suggested for separating a country into workable forecast areas. Consideration is then given to the various rules of procedure in the art of weather prediction, by which, for example, one may map out the position of a discontinuity or foretell the probable development of a cyclonic system. Considerable attention is given to Guilbert's rules, and the tendency to persistence of certain weather types is discussed.

The third chapter of this section makes a direct appeal to the forecaster by giving a detailed analysis of two weather situations—13th March, 1913 and 1st June, 1924. In each case the sequence of weather is examined in the light of modern methods of forecasting from synoptic charts.

The fourth chapter finds the author in a philosophic mood with regard to the place of forecasting in the science of meteorology and to the value to be placed on it. He decides that it is a useful and legitimate extension of the science whose practice, however, is neither easy nor straightforward. Certain difficulties, if not avoidable, are at least able to be appreciated, such as the difficulty of forecasting precipitation inland which accounts for mariners having more faith than, say, farmers. But the unknown factor of a fickle public appreciation is one with which it is impossible to cope. The most one can do is to fix a forecast terminology and aim at some objective test of results. With this object, Prof. Defant endeavours to substantiate an empirical formula which is similar to the law of probability, and various observations are given in support of it.

The forecaster, who has to cater for a large public, will no doubt agree with Prof. Defant. There will always be a considerable number who subconsciously confuse forecasting with the power to control the elements and whose meteorological vision is unfortunately no larger than an umbrella or a rain insurance policy; but, with the development of aviation, an increasing section of the public is becoming enlightened meteorologically, so that for certain restricted purposes at least, the use of a hard and fast terminology, instead of doing justice to the forecaster, may be an actual handicap.

The third division of the book gives an interesting resumé of research into long period weather variations, and the possibility of present knowledge of cyclic changes providing a basis for long range forecasting is discussed.

Prof. Defant has produced a very useful book whose success depends not on formulating any revolutionary ideas of forecasting but in pre-

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senting the subject according to a well conceived educational plan. In that the treatment is not mathematical, the book should appeal to those whose interest in the subject is unequal to the onset of serried equations. The many weather charts and diagrams are extremely well presented.

E. T.

Lehrbuch der Geophysik. By DR. B. GUTENBERG with the co-operation of E. A. ANSEL, Freiburg; J. BARTELS, Potsdam; H. BENNDORF, Graz; A. BORN, Berlin; F. LINKE, Frankfurt a.M.; A. SIEBERG, Jena; L. WEICKMANN, Leipzig. Berlin (Gebrüder Borntraeger), 1926. 8vo. Lieferung 1. Pp. 176. 9,75 G.M.

We have received in the Society's library the first part of a Textbook of Geophysics, which is appearing under the editorship of Dr. B. Gutenberg. The book aims at giving a comprehensive survey of the state of our knowledge of the physics of the globe and the co-operation of the following well-known scientists is promised: E. A. Ansel (Freiburg), J. Bartels (Potsdam), H. Benndorf (Graz), A. Born (Berlin), F. Linke (Frankfurt), A. Sieberg (Jena), and L. Weickmann (Leipzig). It will probably appear in five parts and at the present time no date can be given for its completion; we understand, however, from the publisher's notice that four parts are already available. Part I., in which Professors Born, Ansel and Sieberg collaborate, deals with the earth's crust. A glance through its pages convinces us that the authors are achieving the task which they have set themselves and are providing a book of reference which will collect together the vast amount of information scattered throughout the literature of the various branches of knowledge that go by the collective name Geophysics. The volume is well printed and the illustrations are both plentiful and well reproduced. We look forward to the receipt of further parts with interest, and propose in due course to make them the subject of a more extensive review.

World Weather Records. Collected from official sources by Dr. FELIX EXNER, Dr. G. C. SIMPSON, Sir GILBERT WALKER, H. HELM CLAYTON and ROBERT C. MOSSMAN. Assembled and arranged for publication by H. HELM CLAYTON. Published under grant from JOHN A. ROEBLING. *Smithsonian Miscellaneous Collections,* Volume 79 (whole volume). 1927. 8vo. Pp. viii + 1199.

This volume has been compiled and published in response to a resolution passed at the International Conference at Utrecht in 1923 which asked for the publication of long and homogeneous series of observations in the form of monthly means of pressure, temperature and rainfall in consideration of Prof. Exner's proposal about the calculation of the correlations between the weather-anomalies in regions far from each other.

It contains the monthly and annual values of pressure, temperature and rainfall at 388 stations in different parts of the world; 500 to 1,000 kilometres is set down in the resolution as the normal mutual distance; 1,200 tables afford a distant prospect of at least half a million correlation coefficients. Sir G. Walker has made the selection for Asia, Prof. Exner for Europe, Mr. Clayton for America and Dr. Simpson for Africa, Australia and the Oceans.

The length of the records is variable. A rapid survey shows a range 1917 to 1924 for Dutch Harbour Alaska and 1764 to 1924 for Milan.

Every meteorological library in the world must of course possess a copy of the book, and other institutions may profit by it.

A meteorological school at one of our universities, Cambridge for example, is not a practical proposition in existing circumstances for lack of a suitable library. In this respect meteorology is different from all the other sciences. In astronomy, observers are all observing the same

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celestial objects, and the observations supplement each other. In meteorology observers are all observing different objects, no two sets of observations deal with the same object. In geology that may also be the case, but a geological survey once made stands good till a better is required. In meteorology the survey is chronologically continuous and is never completed. So an adequate meteorological library must provide for the supply of data from every part of the world, many of which are only published as a page or two in an official publication and are only to be found in two or three libraries in any country.

There is already a successful organization for providing data for the few libraries that receive them, there is no regular organization for co-ordinating the data into comprehensive tables for the world. The collection of "World Weather Records" is a notable contribution of the Smithsonian Institution to that important object; and not by any means the first, for the Smithsonian volumes indispensable for a meteorological school would fill a big shelf; this volume is perhaps the fattest of them all.

It may indeed be regarded as a sort of background of the Réseau Mondial which gives year by year monthly and annual values of pressure, temperature and rainfall at about 440 stations, many of them identical with those of the volume now under consideration. The arrangement of stations is, however, somewhat different.

A recent endeavour to present a view of the normal general circulation and its changes has made it clear that the co-ordination of the data for the purposes of study in universities and elsewhere might take the form of an encyclopædia or dictionary to be brought up to date, say once in ten years, which would supply the meteorological student with material at present inaccessible, except for a favoured few, and thus throw open the study of meteorology to a much larger number. Fragmentary compilations are known to professional meteorologists and what is wanted is regular and comprehensive co-ordination.

To such an encyclopædic summary of meteorological data for the globe this volume is a most valuable contribution. Its compilers, printers and publishers may well be proud of it.

"Meteorology stands deeply indebted to Mr. John A. Roebling for providing the means to publish this long desired collection of fundamental data, which cannot but be of great use in future theoretical and practical researches."

And yet one cannot help wondering whether, when they meet, Dr. Exner, Dr. Simpson, Sir G. Walker, Mr. Mossmann and Mr. Clayton, looking upon their joint work, will realize quite fully the complacent creative satisfaction "Behold it is very good." Can they avoid the exclamation "Having got so far, why did we not go one better?" Not all of them could all along have been unmindful of so splendid an opportunity of demonstrating that meteorology is like other sciences in disregarding frontiers; for this volume shouts frontiers all through its pages. 215 stations use millimetre, centigrade and millimetre which are European. 167 inch, Fahrenheit, inch, mainly British and American. A few have got as far as systematic units for pressure; Georgetown Demarara alone carries on its banner two folds of the Réseau Mondial. What an opportunity for the display of magnanimity on the part of one side or the other, or, with the banner of Georgetown Demarara in view, of both! And it is missed!

No doubt the original purpose of the volume is correlation, and one of the beauties of correlation is that units do not matter; but is there not a touch of selfishness in disregarding all the rest of the purposes for which a body of tables can be used? Some like apples and some like onions. Some meteorologists find maps more informing than arithmetic, and they, poor creatures, will have to make conversions before they can make maps. It always seems wasteful to go through the long process

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of conversion for a single object when it might have been done once for all.

And then again the limitation of the data to land stations and to pressure, temperature and rainfall. Can it be supposed that the secrets of the whole circulation are contained in those three elements? Or do the authors contemplate another great endowment of meteorological science with corresponding information about pressure, temperature and rainfall at sea, sea-temperature, winds and other things that are an essential part of the requirements of science but are buried in the archives of the great institutes?

It is, of course, not to be expected that these things could be included in a first endeavour to present the history of the weather of the world; but there is obviously something left for the creators to supply when they are so disposed.

In this bulky volume the traditional month is the time-unit. It is, perhaps, sacrilegious to suggest that when the world has been supplied with so magnificent a collection of monthly data, perhaps rounded off to 1929, the apotheosis of the month might be regarded as achieved and be allowed to rest with its august creator; by that time meteorologists might have considered what to do about it. It is obviously unsatisfactory to go on using units of quite arbitrary and irregular length, that are not even properly correlated with the sun's declination, because they happen to carry the name of "month." There is now enough monthly material in the world to solve the problems up to date which can be solved thereby, and the resources of science should be explored for a better time-unit.

A table of sunspot numbers from 1749 to 1925 by Wolf and Wolfer "from revised numbers by A. Wolfer in *Monthly Weather Review*, Vol. 30, and subsequent volumes," brings the volume to a close; but the preface sounds a disquieting note: "It seems probable, then, that Wolfer's numbers should be multiplied by these percentages with opposite signs to those given, and added to the observed numbers at least since the year 1856." *C'est magnifique mais ce n'est pas la guerre.*

Aviation. The Annals of the American Academy of Political and Social Science, Vol. CXXXI., No. 220, May, 1927. Editor, F. A. Tichenor, 3622-24, Locust Street, Philadelphia. Pp. 205.

The Annals of this institution are issued bi-monthly. This number is devoted to aviation. It consists of 26 articles on its American aspects. As they are mainly of a popular nature, the chief value of the publication is that the general reader has placed together for him what he normally must hunt for in many magazines. If one of its contributors' definition of "art" and "science" may be used, to the effect that "art" always relates to something to be done, "science" to something to be known, this book provides a general review of the progress of the "art" of aviation in America. None of the articles can be called scientific, except perhaps the second, entitled "The Airplane," which is incidentally of little value. The sentence "The landing gear serves in alighting and landing" is typical of the rest of this article. Each article is written by someone connected with the particular subject discussed. Unfortunately, this has led to a great deal of repetition. The articles are of unequal value. The more interesting ones are "Human Flight Throughout the Ages," which gives an amusing account of the very earliest efforts to fly and records an ascent by a certain Simon in the forum at Rome before a crowd that included the Apostle Peter; "Aeronautical Education"; "Aircraft Engineering," which gives an account of the development of aircraft engineering in the past, together with a brief discussion of its present diverse problems; "American Air Transport," which gives a brief account of the present stage of development of air routes and services in the U.S.A.; and "Lighter-than-air Craft." Particular flights

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are described in "Aerial Globe Trotting" and "The First Trans-Atlantic Flight," the first describing the flight of three U.S.A. Army aeroplanes round the world in 1924, and the second describing the flight of the U.S. Navy boats across the Atlantic in 1919. Other subjects dealt with are national defence, the air mail, airports and landing fields, meteorology, air regulations, insurance and commercial factors. The article on meteorology merely indicates the progress made in America towards providing a meteorological service for aviation purposes. The general impression left on the reader of this collection of articles is that, after a general neglect on the part of the Government (except as regards the air mail services) and the public since the war up to 1926, there is now a prospect of very great developments in America. The Air Commerce Act was passed last year and the Air Regulations governing civil flying came into force on December 31, 1926. There are now several internal services in continuous operation, including a daily mail service each way between New York and San Francisco in an average time of 31 hours. The whole of the route from New York to Salt Lake City (Utah) is lighted for night flying with powerful rotating beacons at approximately every fifteen miles.

Uber Luftdruckwellen. Synoptische Darstellung der 24 tägigen und der 8 tägigen Welle für die Zeit vom 10 Dezember 1923 bis zum 19 Febr. 1924. Von PAUL MILDNER. *Leipzig, Geophysikalische Instituts der Universität, Veroffentlichungen, Band* **3** *(Ser. 2), Heft 3,* 1926, pp. 173-240, pls. 9.

Mildner begins his paper with a valuable synopsis of the results of earlier researches into short periods in variations of pressure. Vercelli carried out an investigation of periods in barograph records, and found periods of 2-3, 4, 4-6, 8 and 16 days, and one month. He found, however, that these periodicities were not persistent, but tended to die away without warning. Vercelli's work was continued and partly confirmed by Matteuzi and others. Weickmann in "Wellen im Luftmeer" showed that from time to time records of pressure showed points of symmetry, so that the variations of pressure after these points were mirror reflections of those coming before, and assuming that the points of symmetry were due to all the waves in the pressure variations reaching their maximum (or minimum) simultaneously, he found periods of 5, 7, 11 and 21 days.

Mildner gives a table showing all the points of symmetry found in the records of pressure at Hamburg during the interval 1914-25. Of the nineteen points enumerated, fourteen occur in December or January, one in November, and the remaining four in June or July. During the winter of 1923-24, two such points were found, one on November 6, 1923, the other on January 15, 1924, seventy days apart. Mildner assumed that the main periods are submultiples of 72 days, and took the 72 days which have January 15, 1924, at the middle of their range. He carried out a Fourier analysis of the records of pressure for stations spread over the whole of Europe, Egypt, Spitzbergen, Greenland, and the eastern coast of North America. He found that only the 24-day and 8-day periods were important. The amplitudes of each of these periods is represented graphically, the former showing two centres of maximum, one off the S.W. of England and one over Spitzbergen, the amplitude being 12.3 mm. over Spitzbergen and 10.3 mm. at Scilly. Diagrams are reproduced showing the progression of phase, and on the basis of the assumption that the disturbance is propagated normally to the line of equal phase, he concludes that the disturbance is propagated in a roughly south-easterly direction across the Atlantic. The 8-day period showed a clearly defined centre of maximum amplitude over southern Scandinavia and a minimum over the central Mediterranean.

A chart is reproduced showing the mean pressure distribution over the area concerned for the 72-day interval. A series of charts is also

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reproduced showing the effect of superposing on the mean pressure distribution the variations due to the 24-day wave, and a further series of charts show the effect of superposing on the mean pressure the variations due to the 8-day wave. Finally, Mildner gives a series of charts showing the effect of adding both the 24-day and the 8-day waves to the mean distribution, and alongside each of these charts he shows the synoptic charts for the corresponding dates. The resemblance between the computed and the actual synoptic charts is in most cases reasonably close, at least in general outline, showing that for the interval in question the main changes of pressure could be represented by the superposition of two waves of periods 24 days and eight days respectively.

It must be emphasized that Mildner's computations apply only to the 72 days which he analyzed. They cannot be used for extrapolation or forecasting. The method is only applicable to an interval of time within two points of symmetry, or at best to an interval of time centred at a point of symmetry. It is suggested in the paper that the greater frequency of points of symmetry in winter is due to the greater steadiness of temperature conditions in the troposphere in winter as compared with other seasons of the year. Their non-occurrence in spring and autumn would be accounted for by the rapidity with which conditions in the troposphere are then changing. The distribution of amplitudes of the 24-day period appears to vary with the character of the winter, since during the warm winter of 1925 the centre of maximum amplitude in the region of Spitzbergen was not present.

In Figs. 4 to 7 Mildner reproduces for eight stations the curves showing the observed pressures and the pressures computed from the combination of 24-day and 8-day waves. The two curves agree fairly closely for Greenharbour, where the 72-day interval showed three complete swings of 24 days, but at Scilly we find considerable deviations, particularly for January 8 and 9, 1924, when the differences amounted to about 30 mm.

The amount of labour involved in Mildner's research was obviously very great. The value of the results obtained is difficult to assess, and in any case it is safe to say that this paper cannot have its full value appreciated until it is correlated with similar researches for other periods. We gather from the closing paragraphs that similar researches are to be published at an early date. It is possible that the result of a series of such researches will help to throw light on the physical and dynamical processes in the atmosphere, though it does not appear probable that they will materially help to increase accuracy in forecasting. The oscillations which produce the simple waves of pressure appear to be damped out after a time, since there is no phase relation between their appearance in successive winters.

D. BRUNT.

Das Problem der technischen Wetterbeeinflussung. Von Dr. AUGUST WENDLER. (Probleme der Kosmischen Physik. Herausgegeben von Dr. Christian Jensen und Dr. Arnold Schwassmann, No. IX.) Hamburg (Henri Grand), 1927. Size 9in. x 6in., pp. 107. RM. 6.50.

The title of this book may be rendered "The Problem of Technical Weather-influencing." The work is a discussion of the various attempts that have been made by man to influence the course of the weather or the character of climate, and the methods involved are considered in the light of the physical processes of the atmosphere, and of the circulation according to the principles of the Polar Front. On the more familiar side of the subject we have accounts of the hydrological effects of afforestation, of smoke-screen devices for the protection of vegetation against frost, and of shooting the clouds to avert hailstorms by interfering with the sub-cooling of the water drops. On the less familiar side various chemical and electrical means for promoting condensation and dissipating fog are described. It is claimed (pp. 96-97) that artificial

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rain at Los Angeles, California, has been successfully induced by means of a weather-tower discharging electric waves through the surrounding atmosphere, and that within 15 to 30 minutes the clouds in the vicinity of the tower had already a certain degree of saturation. If, on the other hand, the initial natural conditions were unfavourable to condensation, the machine must be maintained in activity many hours before precipitation is induced. The results of these and similar experiments are recorded by a writer who is a meteorologist, obviously knowing what he is talking about, and it would be mere prejudice for anyone, without experience, to disallow the possibility of local light rainfall being generated through such artificial means. There is no subject, however, that needs more careful handling, or clearer thinking, whether on the part of an author or his reviewer, than the general question of the control of the weather by human agency. This is, of course, a favourite field of cranks, against whom a firm stand has to be made by scientific authority. Now the conception of the control of the weather by man is twofold, implying either a deep-seated, radical control, or a superficial local control. Presumably, no man of science in his senses—one might say no intelligent, educated person—dreams of the former kind of control ever coming within the range of practical politics. Obviously, to control the genesis and movements of air currents over the globe and associated cyclones and anticyclones would be on precisely the same footing as controlling the ocean tides or even the motion of the heavenly bodies. It therefore behoves those men of science to whom optimistic views are attributed concerning the future possibility of weather control to take more pains than they are wont to make it clear that it is not this kind of control which is visualized. But if ever a race of supermen *did* arise with powers over the course of the weather, we fear that it would be beyond the power of any League of Nations to avert war. The earth's atmosphere is a unit of interdependent parts, and you could not derange the weather in England without causing unwanted effects elsewhere. Dr. Wendler does, indeed, hint at possible political complications in connection with the general question, but does not appear to realize that these would be outstanding in anything approaching radical control of the weather. To turn now to superficial, local control, which is the burden of Dr. Wendler's thesis, it is clear that this must needs be very limited, a mere scratch, as it were, on the surface of things, the effect being in the main to enhance natural tendencies in any direction without disturbing the general equilibrium of the atmosphere. To what extent this superficial sort of weather control is worth developing by meteorologists is a question for economists to decide. Dr. Wendler is rather optimistic; but he does not appear to differentiate sufficiently between the two kinds of control—one that would, were it possible, radically alter the natural course of the weather and seasons, and the other, an accomplished fact according to the evidence adduced, that does not.

One might conclude with the comment that success in long-distance weather forecasting—of actual weather sequences, not simply of deviations from seasonal normals—would virtually constitute the most satisfactory form of "control" over the weather since it would save many lives in storms as well as much economic misfortune. But here again we seem thwarted. Has it not been shown by an English meteorologist that even if observational data could be provided in adequate quantity for the purpose of calculating the emergence of one condition of the atmosphere from a previous phase, the time would have elapsed before the prediction could be calculated?

L. C. W. B.

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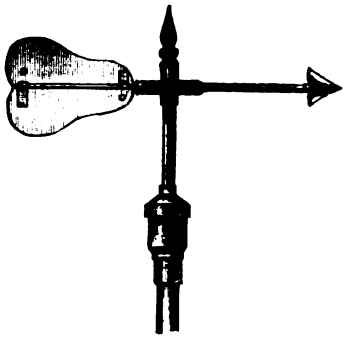

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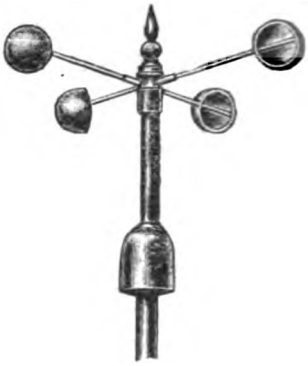

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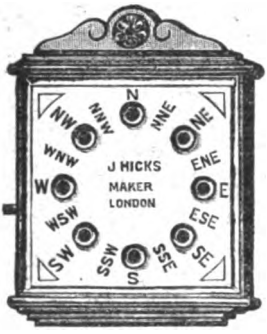

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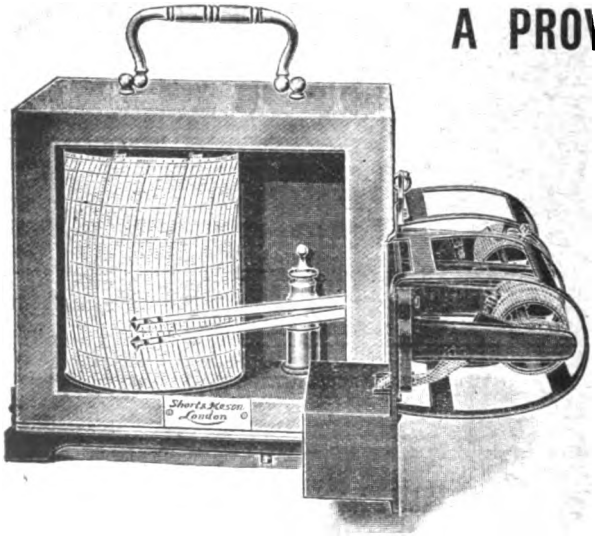

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by the late
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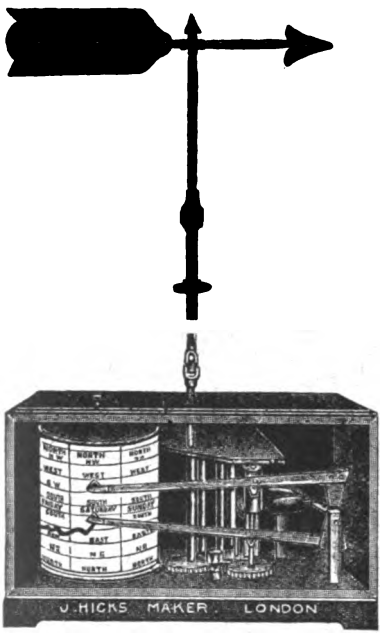

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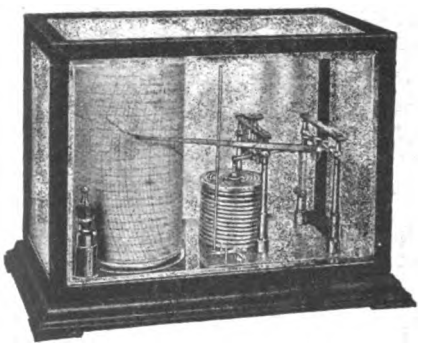

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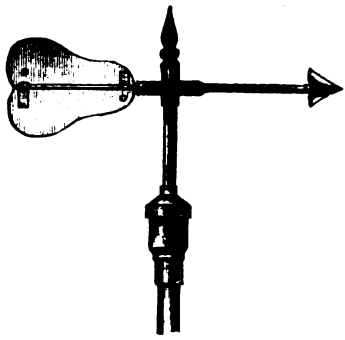

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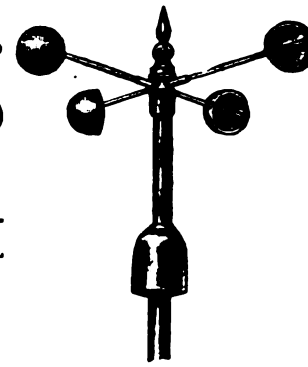

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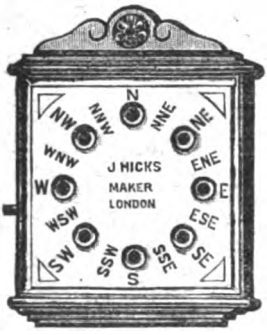

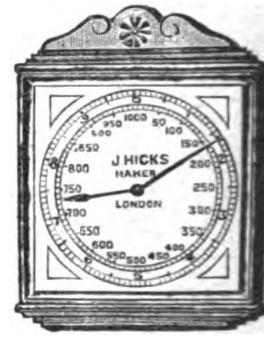

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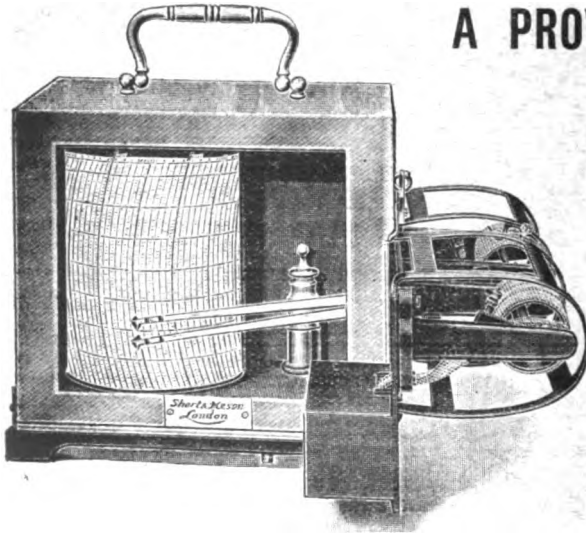

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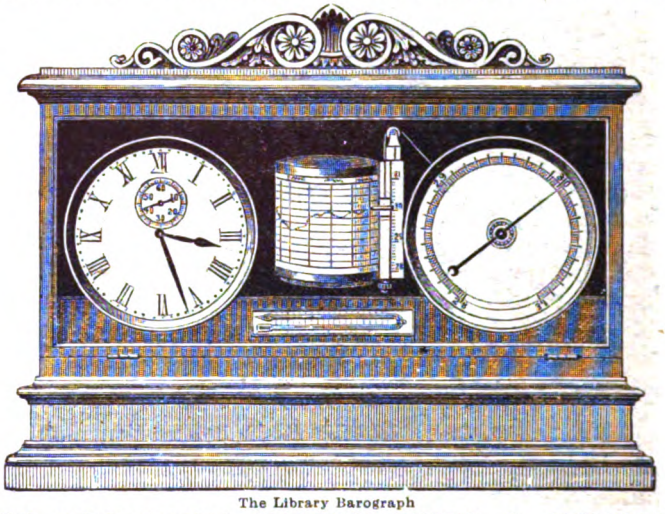

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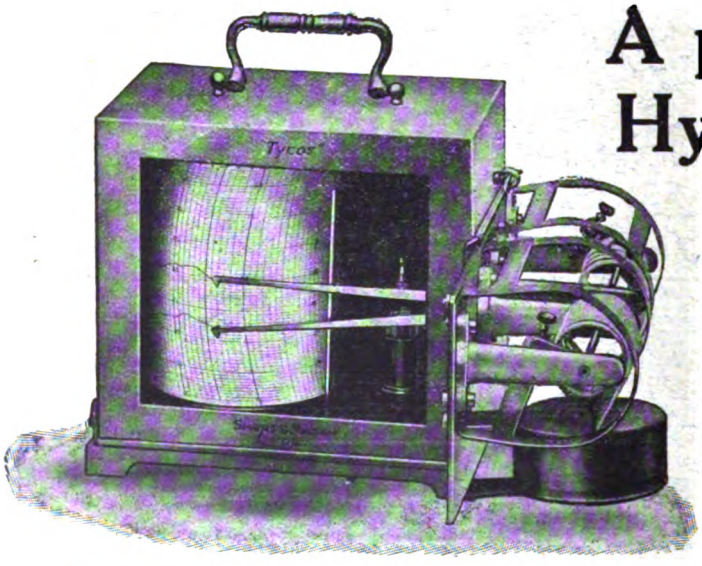

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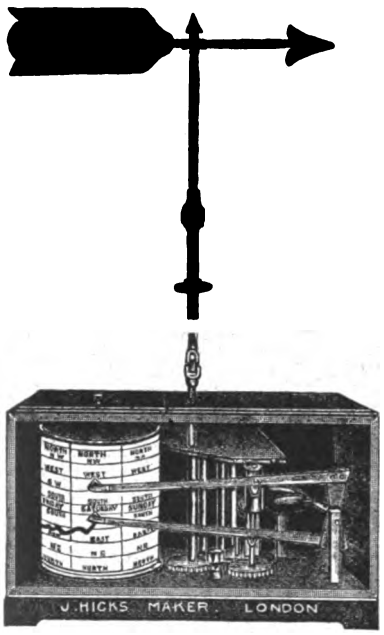

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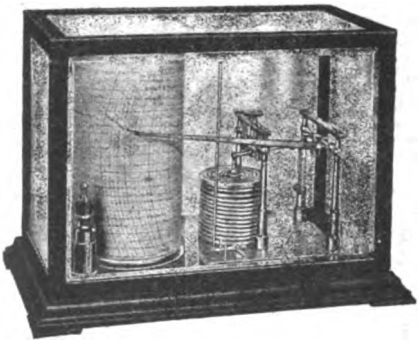

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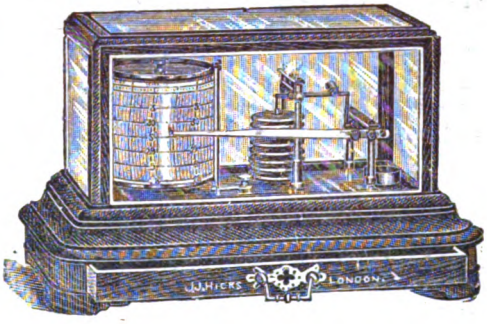

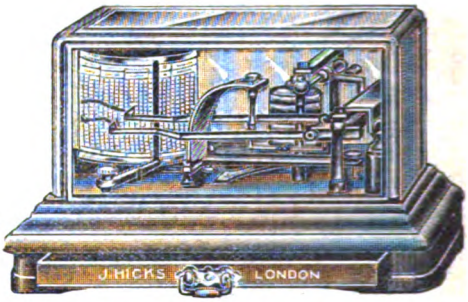

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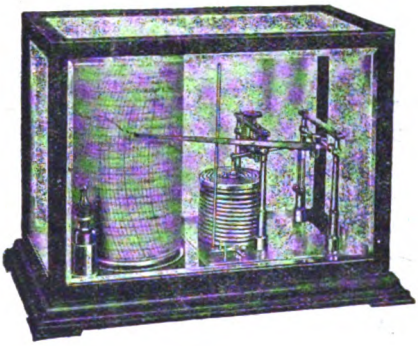

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